cue for survival

OPERATION CUE

A.E.C. NEVADA TEST SITE

MAY 5, 1955

A report by the FEDERAL CIVIL DEFENSE ADMINISTRATION

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FOREWORD

Reports of technical tests contained herein are based on preliminary weapons test reports resulting from Operation Cue at the Nevada Test Site. Some projects require prolonged analysis or laboratory work that will delay the reports of the results for many months.

Civil Defense is based on accurate knowledge of the effects of weapons that might be used against us. Operation Cue greatly increased our knowledge of such effects. However, obtaining knowledge is only the first step. It must then be passed on to the people who can use it. Here, too, Operation Cue was successful. Long after our public media completed their excellent coverage of the operation, civil defenders who participated or observed were spreading the civil defense story through writing and personal appearances.

We cannot praise enough those who helped make Operation Cue a success. To the civil defense volunteers of the field exercise, media representatives and observers who stuck it out, our colleagues of the other participating Federal agencies, and the many participating industries and their technical representatives, we give our heartfelt thanks. To achieve the kind of civil defense preparedness this Nation must have, we need this cooperation and unselfish effort in every phase of our activity.

VAL PETERSON

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INTRODUCTION

The Operation Cue nuclear explosion took place at 5:10 o'clock Thursday morning, May 5, 1955, on Yucca Flat, at the Nevada Test Site of the Atomic Energy Commission. The device was detonated as part of the AEC developmental program. It took place on a 500-foot steel tower and was equivalent in power to approximately 30 kilotons of TNT.

There were 65 associated experiments in this test. The effects studied included 17 diagnostic, 9 military, and 48 civil effects projects.

Operation Cue was the fourth civil defense participation in Nevada atomic tests. Its activities were composed of 3 major elements: (a) an observer program, (b) a field exercise program, and (c) the civil effects tests.

In the first, the Federal Civil Defense Administration continued the program of informing the public, their officials, representatives of business and industry, and members of the information media on the effects of nuclear weapons. The high point of the observer program was the detonation. In addition to this all observers received extensive preshot and postshot briefings on atomic blast, thermal and nuclear radiation, precautions for public safety, and objectives of the experiments.

The field exercise program represented the first participation of this kind by volunteer civil defense workers. These representatives of civil defense services came from all over the Nation to witness the explosion. They were organized by services to operate as a team, exchanging ideas, conducting simulated exercises, and preparing themselves for communicating their experiences to their associates at home.

In the civil effects tests, FCDA sought information on nuclear effects in six program areas: (a) response of residential, commercial, and industrial structures and materials; (b) foods and foodstuff; (c) shelters for civilian population; (d) utilities, services, and associated equipment; (e) mobile housing and emergency vehicles, and (f) radiological defense. Many of the projects were made possible through participation and support of business and industry. Over 200 companies and associations participated, and of the technical project personnel over 100 were from industry.

The objectives of Operation Cue—which was the title given to the civil defense portion of the test program—generally were achieved. About 500 observers were on hand when the shot was fired. The number of civil defense volunteers observing the shot made this program worthwhile, and considerable information of value in the planning and execution of future programs was obtained.

Technical programs and projects were conducted as planned, with the exception of those depending on radioactive fallout on test structures. Unfortunately fallout did not occur in sufficient quantity to obtain the desired results. Final reports on the technical projects are being released individually as completed. Information in this booklet is based on preliminary reports. In addition to these reports, briefing materials of value are included for permanent record purposes.

Photographs and motion picture footage of Operation Cue are available for lecture and training aids. For information, write to Education Services, FCDA National Headquarters, Battle Creek, Michigan.

TEST RESULTS

Damage to Conventional and Special Types of Residences Exposed to Nuclear Effects (Project 31.1)

In Project 31.1, 10 residential structures of wood, brick, lightweight reinforced concrete block, and lightweight precast concrete slabs were exposed in pairs.

The objective of exposing these houses was to test their behavior and resistance to nuclear weapons effects. This project was concerned primarily with blast and radiation effects on structures; precautions were taken to avoid ignition of the structures by the thermal energy of the explosion. Data obtained are expected to be useful also in developing methods for strengthening the structures within limits of practical economy, and in providing information on the possible postattack use for housing without major repairs.

A similar test involving 2 typical American houses of wood frame construction had been held in March 1953. Many significant phenomena were demonstrated by this earlier test, and results of the study were incorporated in the redesigned 2-story frame houses included in the 1955 test. For example, the connection between the exterior walls and the foundation, a failure in 1953, was improved. In the basement reinforced concrete shear walls replaced the pipe columns that had tipped backward in the 1953 test. There was an increase in the size and a strengthening of the connections of the first floor joists. Plywood was substituted for the gypsum lath and plaster which was almost completely destroyed 2 years before. The rafters and wall studs were increased in size. In general, there was superior nailing and fastening providing greater holding power. This strengthening amounted to an increase of approximately 10 percent in overall cost of construction.

In Operation Cue, one house of each pair was placed at an overpressure range where collapse or major damage might be expected. The duplicate was placed at an overpressure range where damage without collapse might be expected.

The redesigned 2-story and basement, center hall, frame houses, painted white with reinforced concrete basement foundation walls were located at 5,500 feet and 7,800 feet from ground zero.

The second pair consisted of 2-story and basement, center hall, wall-bearing houses of brick and cinder block. Floors, partitions, and roof were of wood framing. Basement foundation walls were of cinder block. These

were located at 4,700 feet and 10,500 feet from ground zero. These 2 houses were similar in size and layout to the frame houses exposed in 1953, but the construction generally was conventional, with no attempt having been made to strengthen the structures through special design.

A third pair was a single-story, wood frame, rambler type, painted yellow, and built on a poured-in-place concrete slab at grade. They were of conventional design except that they contained an aboveground shelter consisting of the bathroom walls, floor, and ceiling of reinforced concrete, with an auxiliary blast door and window shutter. These were located at 4,700 feet and 10,500 feet from ground zero.

The fourth pair consisted of single-story houses made of precast lightweight expanded shale aggregate concrete wall and partition panels, joined by welding matching steel lugs, and similar roof panels anchored to the walls by special countersunk and grouted connectors to the wall steel. The precast walls were supported on concrete piers, and the concrete floor slab, poured in place on a tamped fill, was anchored securely to the wall panels by means of a perimeter reinforcing rod held by bolt hooks. Each house had an attached garage; the entire structure was painted white. These were located at 4,700 feet and 10,500 feet from ground zero.

The fifth pair consisted of 1-story houses built of reinforced lightweight expanded shale aggregate masonry blocks. The floors were poured-in-place slabs at grade. Walls and partitions were reinforced with steel rods anchored into the floor slab and the precast lightweight concrete roof slabs. The walls were also reinforced with horizontal steel at 2 levels and openings were spanned by reinforced lintel courses. These were located at 4,700 feet and 10,500 feet from ground zero.

Test Effects (Thermal)

Exterior woodwork of the houses was painted with light-colored paints to minimize the possibilities of ignition by thermal radiation. All windows facing the blast were protected by either Venetian blinds or white opaque coatings on the glass to prevent thermal radiation entering the houses and causing fires by ignition of draperies, furniture, or mannequins' clothing.

On the front of the buildings facing the blast the exterior woodwork of the 2-story brick and cinder-block house, and the 1-story frame rambler, on the 4,700-foot line, was severely charred. Charring also was observed on the 2-story frame house on the 5,500-foot line. The 2-story frame house at the 7,800-foot line showed scorch on the gray-painted shutters but not on the white paint used on the exterior siding. As in the 1953 house tests the motion pictures showed no flaming at any time.

Test Effects (Blast)

The 2-story brick house at 4,700 feet was demolished beyond repair aboveground. Exterior brick and cinder block walls were exploded outward into the yard around the house, very little masonry debris falling on the floor framing. The chimney fell to the side of the house and lay on the ground broken into large sections. The roof was demolished and blown off, the rear side of the roof being lifted off and deposited on the ground on the far side of the house about 50 feet to the rear. Some of the bearing partitions were still standing but badly racked. The first floor partially collapsed into the basement as a result of the fracturing of the floor joists at the center of the spans probably caused by the overpressure loading, and the load of the second floor which fell on it.

The 1-story frame rambler at 4,700 feet was demolished beyond repair, and only the reinforced concrete bathroom shelter remained intact. The roof was blown off, one section of the roof lying 100 feet to the rear of the house; rafters split and broken; sidewalls at gable ends were blown outward and fell to the ground about 75 feet to the rear of the house. A portion of the front wall was still standing but leaning inward.

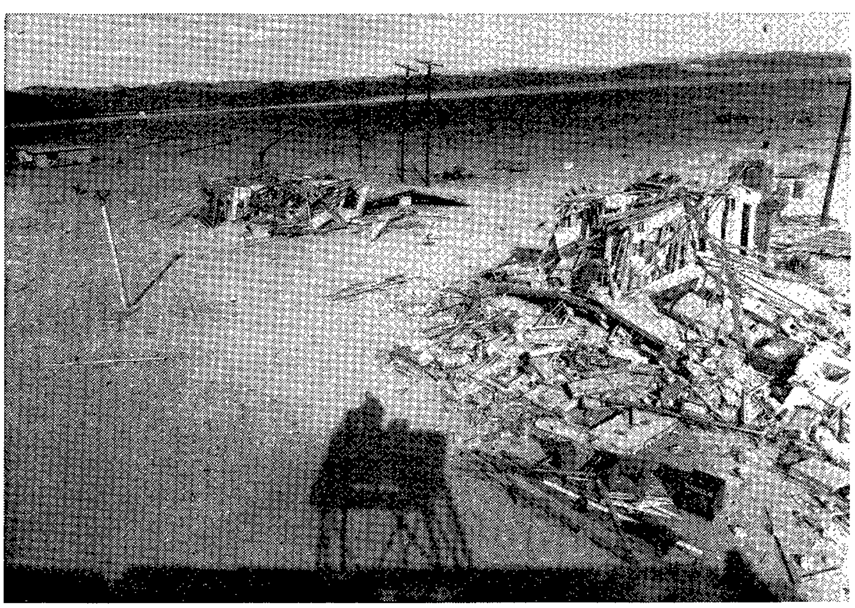

Figure 1.—The 4,700-Foot Line—A photographer atop a camera tower (shadow in foreground) makes an early pictorial record of blast damage at the 4,700-foot line. Wreckage of the 2-story, nonreinforced brick residence is at the right; the frame rambler debris is to the upper left. Note television set in right foreground.

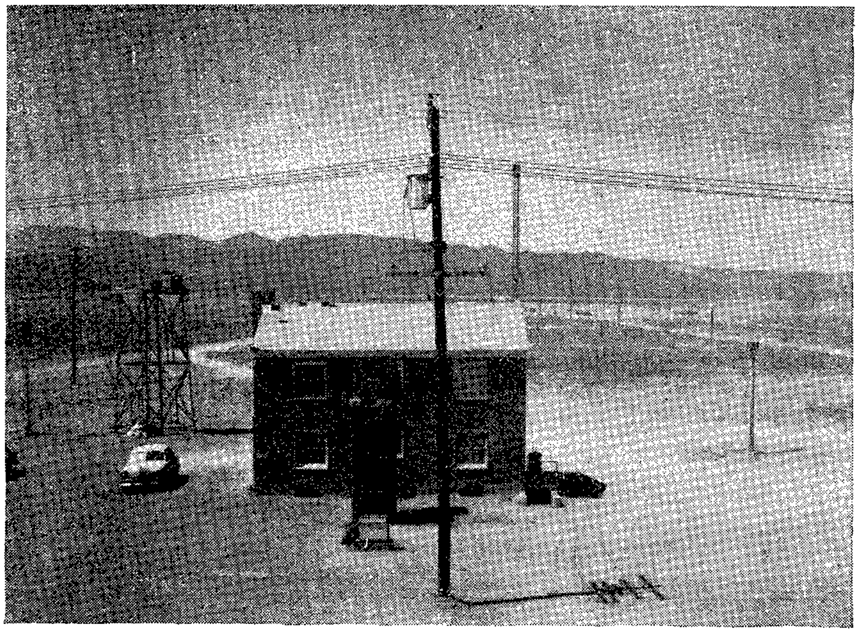

Figure 2.—Test Residence (Before).—A view of the 2-story, nonreinforced masonry and brick "home" at the 4,700-foot line before the detonation. In the foreground is a large hydraulic press, with a missile trap at its base. Autos at the left contain communications equipment. Automatic cameras are mounted on the tower to the rear of the vehicles. The actual shot tower may be seen in the distance.

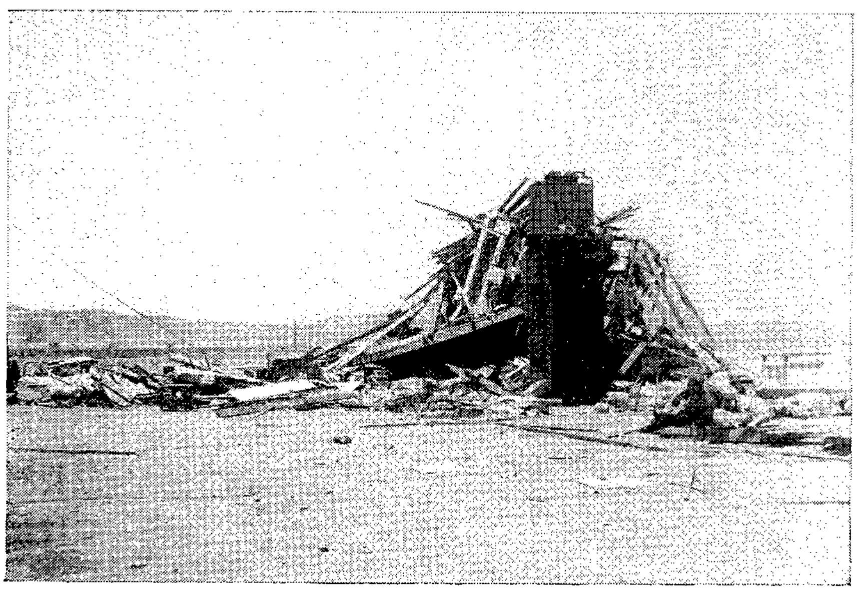

Figure 3.—Test Residence (After).—All that remained of the home shown in figure 2 following the blast. The automobile to the left is crushed under the debris. In the right foreground lies a test mannequin. The hydraulic press, still standing, later was found to be operable.

The 1-story precast concrete house at 4,700 feet withstood the blast with only very minor structural damage, and by replacement of demolished or badly damaged doors and windows could be made available for occupancy.

There was some indication that the roof slabs at the front were lifted slightly from their bearings but not sufficiently to break any connections. The rubber gasket between the roof slabs and walls was blown loose and showing. The walls were cracked slightly over the kitchen window and at the rear corner of the garage. The side wall of the garage was cracked due to bowing outward at the center of the span, leaving an inch space between floor slab and wall. In the rear bedroom joints showed some evidence of movement at lug connections. In certain areas the concrete around the slab connectors spalled, showing the connectors. The steel sashes in the windows generally remained in place but were distorted. Glass in the front and side windows was blown out as well as in some of the rear windows. The aluminum garage door was blown into fragments. Exterior doors to the house were demolished. No doors were installed in the partitions.

The 1-story masonry block house at 4,700 feet withstood the blast with only minor structural damage, and by replacement of the doors could be made available for occupancy.

There was some minor evidence that the roof slabs had been moved from their bearing, but not sufficiently to break any connections. The unreinforced portion of masonry wall under the front living room window was pushed in about 4 inches. Exterior doors were blown inward and completely demolished. Glass in front windows was blown in, the steel frames being distorted, but remaining in place. The rear windows, glass and frames, were blown out.

The 2-story frame house at 5,500 feet superstructure suffered severe damage and the house would not have been suitable for occupancy without extensive major repairs which would not be economically advisable. Certain of the redesigned features appeared to perform their function well, particularly the reinforced concrete foundation wall, the shear walls supporting the main girders in lieu of pipe columns, the improved connections between the frame walls and concrete foundation walls, and except on the front of the house, the improved window frame anchorage. The strengthened superstructure was still inadequate to resist the overpressure to which it was subjected.

The front half of the roof was broken at the midspan and the entire roof framing deposited on the ceiling joists. Most of the 2″ x 8″ rafters split lengthwise. The rear half of the roof was lifted from the house and dropped to the ground 25 feet to the rear of the house with most of the shingles still attached. Large sections of plywood ceiling were blown down into the rooms below. The upper portion of the chimney was toppled

outward at right angles to the end of the house. Above the hearth line the chimney was shoved $2\frac{1}{2}$ inches toward the rear of the house and rotated slightly. The exterior wall to the rear of the chimney bulged out of line several inches. First floor joists were split or broken, with the floor near collapse and held up principally by the sub- and finish flooring. Severe racking was evident throughout the remains of the house. Practically all doors and windows were blown out. The second floor and ceiling of the first floor showed little damage, indicating pressure equalization above and below the floor.

The 2-story frame house at 7,800 feet suffered relatively heavy damage, but its condition was such that it could be made available for emergency shelter from the elements by shoring and not too extensive repairs.

Severe damage was inflicted to the roof and second floor ceiling framing. All framing was severely racked. In the roof framing the cornice board on the front of the house facing the blast was blown off, and it appeared as though a slightly higher pressure would have lifted the roof completely from its attachment to the structure. The ceiling framing was lifted about 6 inches from its bearing and attachment to the dividing partition between the front and rear bedroom. The ridge board was broken and rafters over the rear bedroom fractured. Similar but not so severe damage was suffered by other portions of the roof framing. The center girder over the master bedroom was lifted 2 inches out of its supporting stirrups and pulled away from the ceiling joists. Nails fastening the strap iron joist ties over the center girder were sheared off on the blast side of the house at some joists. Very few of the ceiling joists in this portion of the house were damaged. First floor joists were cracked and fractured, but no debris was deposited in the basement, the subflooring and flooring remaining intact. The chimney was damaged but remained in place. The upper portion was sheared loose and turned counterclockwise about 4 inches, as was a lower portion about 18 inches aboveground.

Shutters at the front were loosened and received some damage but withstood the blast. Wood sashes on the front and sides were blown in and smashed. Rear windows were damaged, exterior doors blasted in, and the stair rail damaged. Damage to walls and ceilings in the first floor was slight. On the second floor damage to ceilings was severe, some of the plywood ceiling boards being blown free of their fastening. Some interior doors were blown from their hinges.

The 2-story brick house at 10,500 feet suffered relatively heavy damage yet it could have been made available for emergency occupancy by shoring and not too extensive repairs.

There was no apparent damage to the masonry. The structure suffered

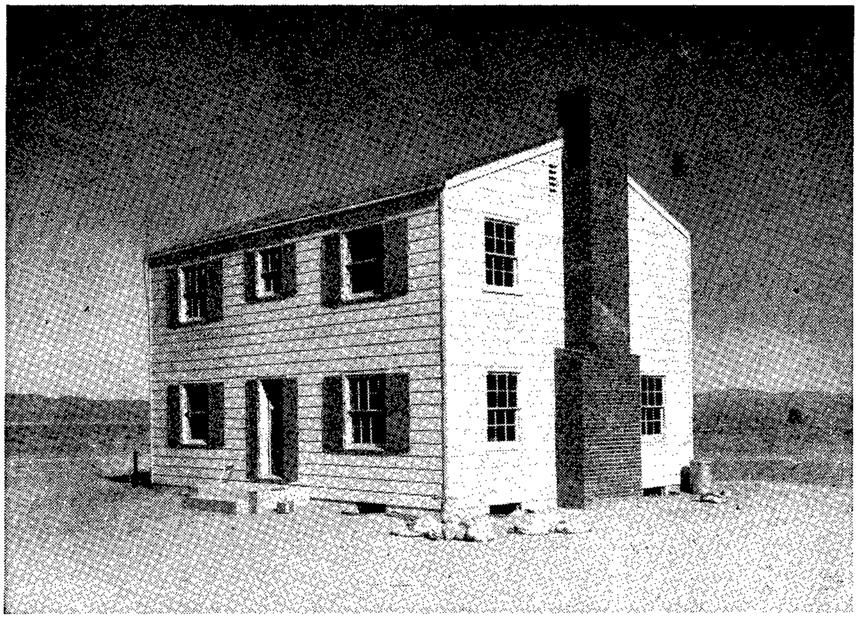

Figure 4.—Frame Residence (Before)—Similar in plan and appearance to the structure exposed in the 1953 test, this conventional residence was redesigned and strengthened to provide a higher degree of blast resistance at a minimum of cost. The building was located at 5,500 feet from ground zero.

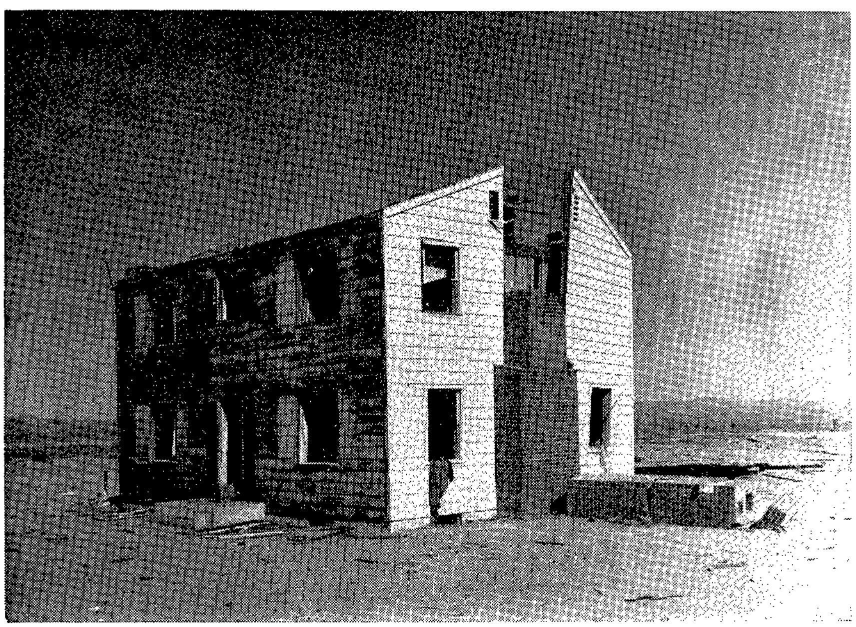

Figure 5.—Redesigned Frame Residence (After)—Although certain of the redesigned features performed well, the strengthened superstructure of this frame dwelling was still inadequate. It would not be suitable for occupancy.

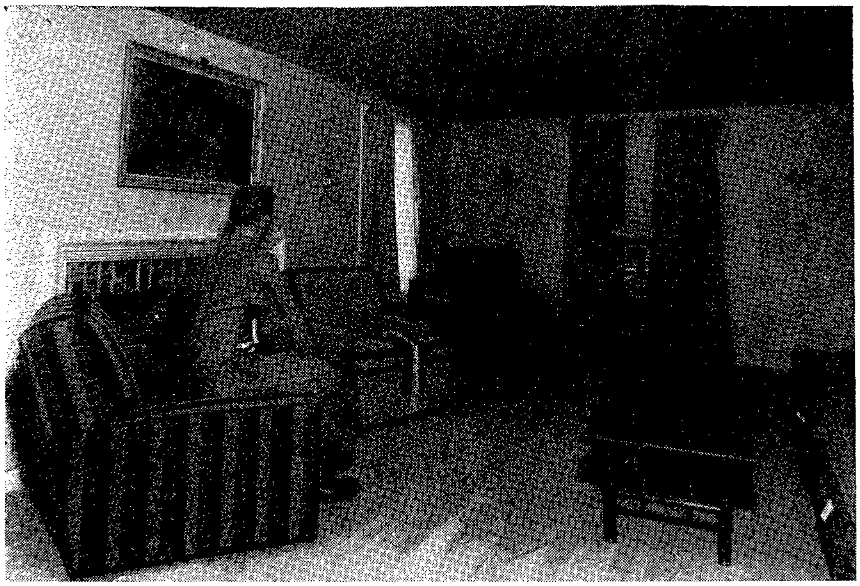

Figure 6.—At Peace—This mannequin "resident" of the 2-story, redesigned, frame home located 5,500 feet from ground zero, enjoys the serene surroundings of his partially furnished living room. The blast will come from the direction he faces. Dosimeters are fastened to walls to record radiation.

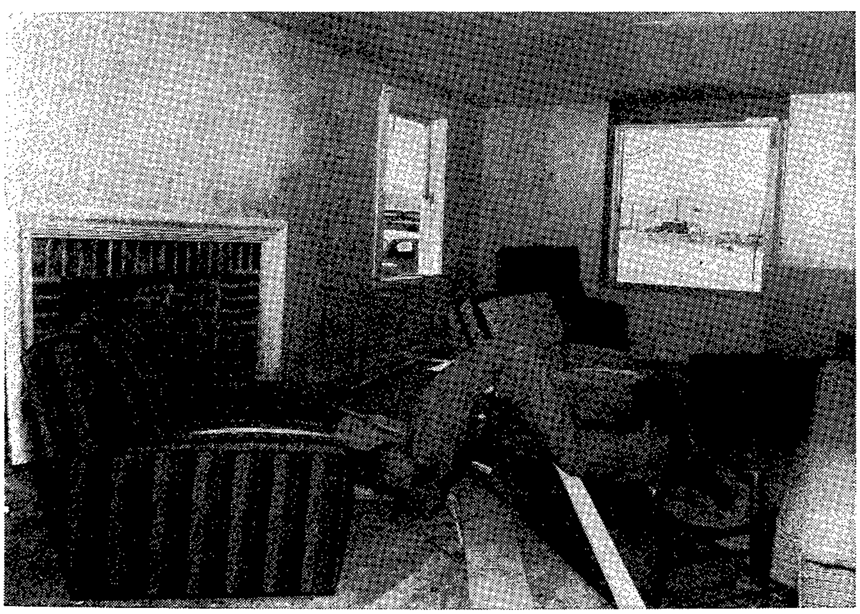

Figure 7.—And Then It Happened—The blast rips out windows completely, along with Venetian blinds and draperies. (See figure 5.) The room is well sprayed with glass splinters. Furniture is upended—as is the mannequin.

considerable damage to the roof and second floor ceiling framing. Connections of the rear rafters to the ridge failed, the rafters dropping 4 to 6 inches, the ridge split in the center portion, and some of the 2″ x 4″ collar beams broke in half. Ceiling joists over the rear bedroom split at midspan, and the lath and plaster ceiling were blown down. Second floor framing suffered little or no damage. A few first floor joists were fractured. Glass in front and side windows was blown in, and several interior bedroom and closet doors were blown off their hinges. The stair rail was broken and the interior plastered wall and ceiling finish was badly damaged.

The 1-story precast concrete house at 10,500 feet withstood the blast in very good condition and by replacement of doors and windows could be made available for occupancy.

Only very minor structural damage was noted; some spalling of the concrete occurred at the lug connections. All glass in the front sash was blown in; some glass blown out of other windows in side and rear walls; steel window sash remained in place but was distorted in shape, and the venetian blinds were blown across the rooms into a mass of rubbish. The exterior doors and the garage door were demolished.

The 1-story masonry block house at 10,500 feet withstood the blast in excellent condition, and by replacement of the doors and windows could readily be made available for occupancy.

There was no apparent damage to the structural parts of the building. The front door was blown across the room, the rear door broken at the lock. The front and side window glass was blown in, and glass in rear windows blown out. The steel sash was warped and twisted but remained in place.

The 1-story frame rambler at 10,500 feet did not suffer heavy damage. A cracked 2″ x 4″ stud located between the front door and window in the living room was noted. The west wall bulged out 4 inches at the ceiling line, and the exterior siding split at the same line; the midspan rafter support beam on the front side was broken, and there were evidences of racking of the structure. Considerable damage was done to the plasterboard walls and ceilings. Glass in front windows was sent flying, and some glass was broken out of all the windows. The steel window sash remained in place with only minor distortion. The steel Venetian blinds from the front living room window were blown through the rear window, smashing the glass. The front door was blown from its hinges across to the rear of the room. The porch roof was lifted up 6 inches off its post supports. Many glass fragments were imbedded in the walls.

Conclusion

The tests of residences in the above program were gross effects tests of the individual types of structures. They were not comparison tests

of types of materials, and the materials used should not be compared for blast resistance on the basis of whether one structure failed and the other did not. Much depends upon how the materials are used in design.

For example, the results of these tests do not indicate in any way that concrete block, as a building material, is superior to brick, or vice versa. A 12-inch 1-story reinforced concrete block wall, heavily loaded by a concrete slab roof, may be expected to resist lateral pressure better than an unreinforced 8-inch 2-story brick and cinder block wall with a wood frame roof load. Further, the greater mass and very small projected face exposure of the concrete roof provided an inertia factor which contributed appreciably more support to the top of the concrete block wall than would have been provided by a wood-frame gable roof.

It has been generally known that a low wall has greater resistance to lateral load than a high wall of the same cross-section; that a steel-reinforced wall is stronger than a similar unreinforced wall; and that an axially-loaded masonry wall has greater resistance to lateral load than an axially-unloaded wall.

In addition, there are many other factors that may affect the resistance of a structure to lateral blast loads, including the geometry of the structure, the percentage of window and door openings and the interior design of floors and partitions.

Damage to Commercial, Institutional, and Industrial Structures and Contents Exposed to Nuclear Effects (Project 31.2)

The objective of Project 31.2 was to expose conventional and special designs of industrial buildings and thus determine, insofar as possible, the survival range of the test structures. Redesign for greater resistance to lateral blast loadings within economic limitations is to be expected as a result.

The project was made possible as a result of the invitation by FCDA to industry to participate voluntarily.

A blast-resistant control room prototype (Union Carbide building) was constructed at the 5,500-foot line. It was built with reinforced gypsum walls and roof poured integral with a welded steel frame. All elements of the building, except for the plastic windows and steel industrial door, were designed to resist a specified blast pressure with some permanent plastic deformations.

Two steel frame buildings with aluminum siding (Butler buildings furnished by Reynolds Metals) were located at 6,800 feet and 15,000 feet,

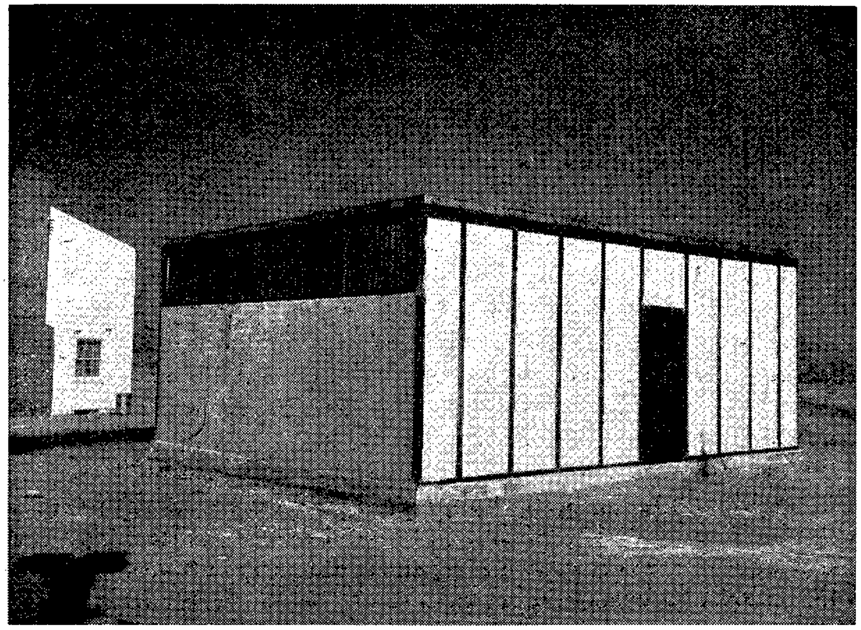

Figure 8.—Union Carbide Building (Before)—This blast-resistant control room prototype, built with reinforced gypsum walls and roof on a welded steel frame, was designed to resist blast pressure at the 5,500-foot line.

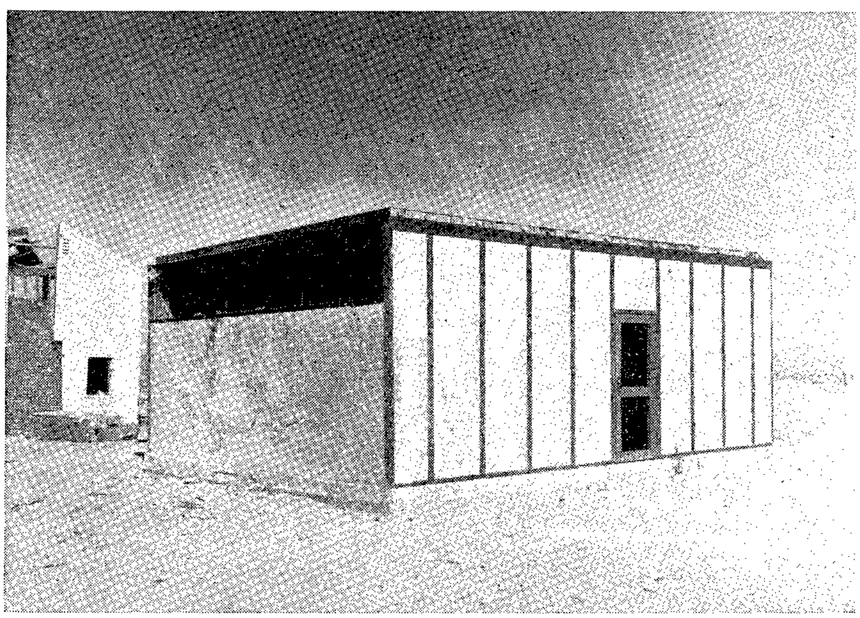

Figure 9.—Union Carbide Building (After)—Comparison with figure 8 shows how little damage this prototype sustained. The plastic windows and the door were not designed to resist blast. Visual inspection showed small deformations of the steel frame but no primary structural damage.

respectively. These are the gable-roof, rigid-frame type buildings of standard construction for commercial buildings. Roofs and walls were covered with light aluminum panels having high-rib corrugations and being bolted to framing members.

Two frameless steel buildings with deep corrugations in side and roof (Behlen buildings) also were located at these distances from ground zero. These are standardized utility structures, monolithically self-supporting without frames, girts, or purlins.

At the same distances were located two frameless steel buildings (Armco buildings) with channel sidewalls. The channels can act both as a column and as a beam, no separate structural frame or girts being needed.

Preliminary visual inspection following the shot showed the Union Carbide control room had suffered very little damage. Although very small deformations of the steel frame were noted, and there was some cracking in the gypsum walls, there was no primary structural damage.

The buildings at 6,800 feet from ground zero were severely damaged.

In the Reynolds-Butler building, the welded and bolted steel frames of the aluminum-covered structure remained standing, but were distorted with deflections of about 1 foot at the eaves. The wall panels were stripped from the front, along with most of their supporting girts and purlins. Panels were in place on the rear slope of the roof, but were mostly disengaged from their fasteners. Girt and panel segments from the center of the front wall were blown through the back wall, damaging machinery en route. Most of the panels on the ends and rear wall, away from ground zero, remained attached.

The Behlen building at 6,800 feet offered good protection to interior contents despite severe damage. All windows and the door were broken, and the front slope of the roof was crushed downward at mid-section between 1 and 2 feet. Front and end walls buckled inward several inches. All of the pieces remained bolted together.

The Armco building at 6,800 feet was completely destroyed, and one or two segments of wall were blown down-blast up to 50 feet. In general, however, the bent and twisted segments remained approximately in their original location, and most of the wall sections remained attached to their foundation bolts. The roof collapsed completely and came to rest on machinery in the interior.

At the 15,000-foot range all utility buildings fared much better than their counterparts at the closer range.

The Reynolds-Butler building retained its aluminum roofing and siding although panels were disengaged. Wall and roof panels were dished inward. Center girts were torn loose from their attachment to the columns on the front face. Aluminum end panels were slightly dished, but sheeting was virtually undistorted on the rear wall and rear slope of the roof. Main

steel frames suffered slight distortion, but the anchor bolts for the rear frame footings were displaced rearward.

The Behlen building suffered little structural damage. Diagonal dimension checks in the interior showed that it experienced no permanent lateral movement at the eaves, and there was no buckling of roof or wall panels.

The Armco building was, in part, severely damaged. The front wall panels were buckled inward from 1 to 2 feet at the center. The rear wall and rear slope of the roof were undamaged.. Roof panels nearest the blast were slightly bent with deflections of from 1 to 6 inches at center, but in general the roof structure remained intact. Glass from front wall windows was blown inward.

In general, all of these buildings at 15,000 feet remained serviceable to the extent that they continued to provide shelter to interior contents in spite of damage ranging from negligible to severe.

It was emphasized that none of the utility buildings was designed in any way for blast resistance. The Behlen building, which stood up well under the blast, may be said to be considerably over-designed for the conventional loads to which it is normally exposed. Furthermore, due to the relatively small size of the structures under test, conclusions may or may not be the same for structures of larger size. The results of the program are expected to permit recommendations for improved design details that may improve their blast resistant behavior.

Thermal Ignition and Response of Materials (Project 31.5)

Project 31.5a

The stake-line test (Project 31.5a) was designed to provide information on the degree of damage to untreated surfaces of sound wood exposed to a wide range of thermal energies from atomic detonations.

The intensity of thermal radiation varies with bomb size, distance from the bomb, and visibility or haze characteristics of the atmosphere. Intensity or radiation falling on any surface is reduced in proportion to the cosine of the angle of rotation of that surface from the one which would be perpendicular to the incidence of radiation. Thus the intensity of radiation on a surface of 45 degrees from the perpendicular would be just 70 percent of that on a comparable perpendicular surface.

The surface of any material subject to thermal radiation is heated, and if the surface is heated to ignition temperature of the material it will burst into flame. At less than ignition temperature, water vapor and other

volatiles are given off as a thermal effect and usually appear as dark-colored smoke.

If thin materials such as newsprint or straw or wood shreds are heated to their ignition temperature, they ignite and continue to burn. These are called kindling fuels. If they have bulk behind the surface, and are considered as thick materials, e. g., plywood, heat on the surface is lost by conduction into the material and flaming will not persist following the thermal pulse. However, if the density is low and they are very poor conductors, they act as thin materials. Moisture content also plays an important role since water in the kindling material must be heated and vaporized before temperature can rise to the ignition point.

In this test a 2-inch x 6-inch x 3-foot stake of Ponderosa pine and one of Douglas fir were placed every 500 feet along a radial line from ground zero, beginning at a ground range of 1,000 feet. Some of the stakes were rotated 30 degrees. Protected control surfaces for comparative purposes were obtained in each stake by covering a 2-inch strip with aluminum foil and by piling dirt around the bottom. Each stake was attached by two U-bolts to a steel fence post which was driven into the ground.

Visual interpretations of the field observations included the following:

No stakes continued to burn. Thus it appears that continuing fires will be started principally by the primary action of thermal radiation on kindling fuels.

The effect of char and scorch was less up to 3,500 feet from the ground zero than between 3,500 feet and 6,500 feet from ground zero. Apparently blast wind at close ranges has the effect of terminating the thermal action before it has run its course.

Project 31.5b

The objective of the treated-timber piling test (project 31.5b) was to observe the behavior of treated timber piling in bridge construction when exposed to an atomic device. In addition, the effectiveness of a white pigmented "fire retardant" coating material was sought in contrast to a black pigmented coating material of the same chemical composition.

Various methods have been used for about a century by the railroad industry for preserving its timber structures. Treated timber has a useful life ranging up to 50 years; untreated timber has less than 10 years. During the past 75 years creosote has been used alone, and more recently in combination with coal tar and Bunker C fuel oil.

Preliminary results from laboratory studies have revealed differences in behavior between species of wood, preservative, and degree of retention, as well as a considerable difference when compared to an untreated specimen.

Figue 10.—Pilings Tested—Wood piling such as those used in railroad bridge construction were exposed, some receiving a "fire retardant" coating. Preliminary post-test evaluations indicated white pigment offered good protecton against thermal radiation.

Thirty 8-foot pile stubs were used in this test. They were placed in 4-foot-deep holes at 4,700 feet, 6,800 feet, and 10,500 feet from ground zero. Twenty-seven poles were treated in various combinations, a third of these being left unpainted. Of the remainder, half received black paint and half white paint. Three unpainted poles acted as controls, and an untreated, unpainted pole was used as an overall control blank.

In terms of distance from ground zero, piling at 10,500 feet was unaffected.

At 6,800 feet, piling showed evidence of thermal damage. The white fire-retardant coated piles were undamaged, the black coated piles were attacked on the frontal surface, and least affected was the creosote-treated pile.

All of the unpainted control piles bled as a result of their exposure to the sun. The viscous exuded preservative which flows slowly down the pile was charred, forming blisters or tubercles which offer some protection against the possibility of secondary fires beginning.

At the 4,700-foot range specimens showed effects which only a complex force such as an atomic device might produce. Again the white coated piles were unaffected. The uncoated controls exhibited considerable exudation of preservative due to exposure to sun, with the creosote-petroleum-treated pile bleeding more than the creosote-treated pile. In each instance charring of the oils on the frontal surface was evident.

The black painted specimens emphasized clearly the significance of color as a protection against thermal radiation. Large patches of protective coating material were blown from the frontal surface of the creosote-petroleum-treated pile. Damage extended over a frontal arc of 180 degrees and was accompanied by an accumulation of dirt and sand which adhered to the oil substrate surface. This accumulation of oil was created by the exuded preservative. Such an effect could lead to secondary fires as well as an accumulation of radioactive dust of variable and dangerous half-life. Specimens otherwise treated were less severely damaged.

When it is assumed that all atomic devices do not behave in the same fashion regarding the production of blast energy and thermal radiation, and the same type of device can produce different effects depending upon weather, size of specimen, location in a structure, etc., it is apparent that conclusions must be applied with care and extended in a general way.

Nevertheless, it is indicated that a particular fire-retardant coating composition, when made to contain a black pigment, offered some protection. The black kinds absorbed heat from the sun, which stimulated exudation of preservative, weakened the bond between paint and the wood, and allowed thermal energy to vaporize the preservative oil and develop sufficient internal pressure to blow off the coating. The oil-soaked timber thus was exposed to easy ignition.

The same material with white pigment offered absolute protection and was unaffected in all locations. Some of this success may be attributed to the fact it offered insulation against the sun and thus, for the 12-day test period, minimized the accumulation of flammable preservative oils beneath the coating. The behavior of similarly coated piles if allowed to weather for one year may or may not bring similar results.

Project 31.5c

The objective of this test was to ascertain the relative reduction in heat penetration afforded by certain materials commonly found on window openings, and materials which might be applied to window glass and openings in buildings under emergency conditions.

The 2 basic causes of fire from an atomic explosion in urban areas are primary fires caused by heat from the bomb and secondary fires caused by blast disruption knocking over heating devices, breaking fuel lines, exposing highly combustible materials to heated surfaces. Thermal action beyond areas of major to complete blast damage will ignite highly combustible materials, and these fires will ignite the more solid combustibles. Interior kindling materials such as draperies and bedding will be ignited by radiation from the fireball through window and door openings. It would not be practical to close up windows solidly, therefore the relative value of methods

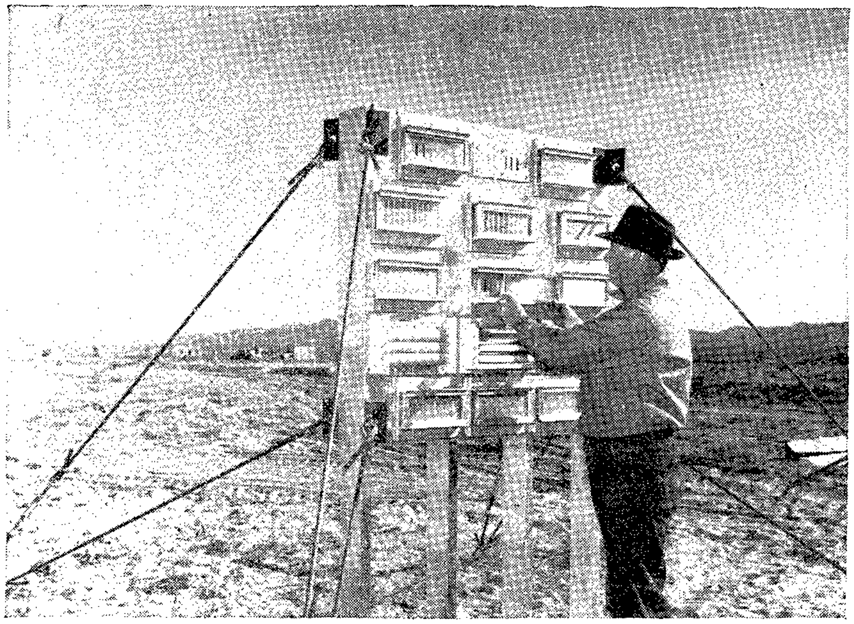

Figure 11.—Screening Out Thermal Radiation—Test racks of various screening materials were exposed to nuclear blast, and showed that excellent protection for household interiors against thermal radiation can be achieved by such simple coatings as whitewash.

which will permit light to enter buildings becomes of major importance in fire prevention.

Test racks were erected at 5 locations ranging from 4,700 feet to 10,500 feet from ground zero. On each rack exposure samples and controls were placed. These samples included window glass, a solid aluminum sheet, aluminum shade screening, Venetian blinds closed and partially open, insect screens, window glass coated, and combinations of these. Instrumentation was provided by heat-sensitive paper.

Preliminary evaluation of the test indicates the solid aluminum sheet provided substantially complete protection of the opening from the effects of thermal energy, and Venetian blind slats fully closed closely approached this near-complete protection. Venetian blind slats at 45 degrees behind glass, and a whiting mixture applied to the glass, afforded a high order of protection.

Of 3 coatings applied to glass (whiting and water, household cleanser and water, and a commercial opaque paint) whiting and water proved most efficient. The presence of glass improved the efficiency of Venetian blind slats set at 45 degrees, despite the fact that glass in itself gave little reduction in thermal energy. Insect screen provided some protection; the effect of mesh density was apparent at the close-in ranges.

Project 31.5d

The behavior of textiles when subjected to high thermal energies of atomic detonations was the objective of the fabrics test (Project 31.5d). Information sought included not only the reaction to heat intensities with respect to physical change and appearance, but to learn in a general way the degree of heat penetration through clothing to skin of the wearer.

Some textile materials fuse or melt at relatively low temperatures, others scorch, char, or burst into flame in successive stages. Melting and fusing of the molten mass is very dangerous to the skin. It is known that dark-colored textiles absorb more heat, and that certain dyes absorb more radiation than others.

In a previous test mannequins dressed in civilian clothing were exposed in houses and trailers. This test was designed to provide more realistic information by exposing dressed mannequins and fabrics outdoors as well as mannequins indoors.

Outdoor exposures included a large range of fabrics and fibers available to the public. Test items were mounted on wooden plaques and also exposed as mannequin clothing. Indoor exposure was given mannequin clothing.

In natural fibers, the dark colors caused more damage than lighter shades. Black wool was severely damaged. Cottons were damaged to a much greater extent than wool, and on the cotton prints the dark designs were burned out. Heavier fabrics stood up better; fireproofing finishes appeared to have some value, but did not necessarily prevent scorching.

In the synthetic fibers, dark colors again caused more damage than lighter shades or white, being especially true of rayons. Most of the synthetics melted or fused, especially in dark shades. Orlon, teflon, acetate, dacron, acrylon, and nylon melted, fused, or burned. A fairly heavy nylon denim (dark blue) disappeared completely. However, a white nylon denim was undamaged. Dynel tended to char and harden; white dynel was hard and curled, whereas grey and green shades completely disappeared. Arnel became very stiff. The fabric with a glossy finish appeared to fare better than one with a rough surface finish.

Several layers of fabrics invariably increased protection. Even when synthetic fabrics fused and disappeared, white cotton knit underwear layers underneath them remained undamaged or lightly scorched. Third and fourth underlayers were completely protected.

Clothing on mannequins behaved in the same manner but was damaged to a lesser degree, partly due to folds and air spaces. Orlon sweaters were not damaged. Rayon slacks of dark color were singed severely. Acetate material melted when exposed as an outer layer.

Project 31.5e

The purpose of Project 31.5e was to learn if thermal radiation from an atomic explosion will damage or explode oxygen and acetylene units, and damage their accessories. Furthermore, it was desirable to learn the thermal effect on vented atmosphere and pressurized chemical storage tanks which contain vapor-air mixtures in the explosion range.

One standard oxy-acetylene unit, consisting of one oxygen and one acetylene cylinder, together with regulators, hose, and torch, was strapped to an "I" beam and set in a vertical position at each of 3 locations ranging from 4,700 to 8,000 feet from ground zero.

In addition, four 55-gallon steel drums were set at each of 2 locations, 5,700 feet and 8,000 feet. Five gallons of CD–17 alcohol were poured into each drum. Bung plugs were removed from 3 drums at each location to simulate vented tanks, and to these 1 pint of ethyl ether was added to insure explosive vapors. The closed drum received 3 cubic feet of acetylene.

There was no apparent damage to any of the oxy-acetylene units due to thermal radiation. No defects were found when the equipment was checked for pressure and operability.

Within 4 hours after the blast, it was determined by gas analyzer that there was an explosive gas mixture in the vented containers, and it is assumed that similar conditions prevailed at the time of the blast. There was no indication of fire or explosion in any of the containers.

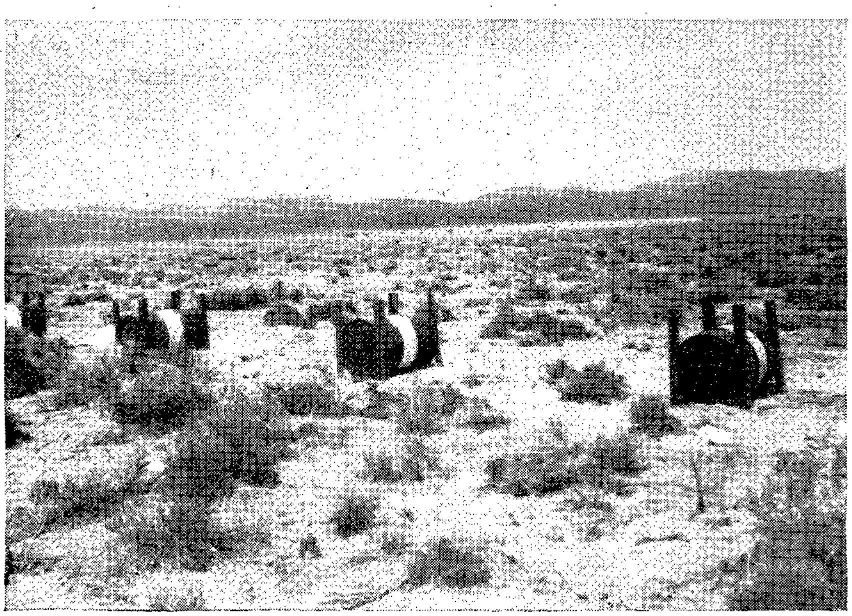

Figure 12.—They Didn't Explode—These 55-gallon drums carried alcohol and ethyl. They did not catch fire or explode.

Project 31.5f

The objective of Project 31.5f was to evaluate the thermal effect of an atomic detonation on samples of plastic materials now on the consumer market, as well as those used widely in industrial applications. The Society of the Plastic Industry, Inc., was the sponsor of this participation.

Six hundred and eighty samples were installed at 3 stations (6,600 feet, 7,660 feet, and 8,690 feet). Film and elastomeric type materials were cut 12″ x 12″ and placed in test frames which were hung on test racks. One-half of each sample was supported by a wood backing. Rigid materials were not placed in frames but were hung directly from the test racks.

The degree of thermal effect depended upon several factors, including the type of material, thickness, color, and the actual distance from ground zero. In addition, during the 10-day pretest period, samples were subject to high winds and dust, some rain, and high heat conditions.

Preliminary evaluations indicated that thermoplastics, as anticipated, were more affected by thermal heat than were the thermosetting plastics; the vinyls showed more definite reaction than any other samples exposed.

Color is a major factor in the reaction of plastics. White and transparent samples exhibited less distortion, char, and melt than did the darker colors. Black samples were affected to a greater degree in all cases. The heat effect varied widely with thicknesses, depending upon the thermal characteristics of the various plastic families.

There was no difference in the effect of the wood backing at either of the closer ranges. If a material melted, it was a complete melt. At the far range, however, those materials which melted at the closer locations usually melted at the unbacked portion.

Methods of Determining Yield and Location of Nuclear Explosions (Project No. 31.6)

Additional tests of several thermal types of air zero locators confirmed the results obtained in the 1953 test series as to the workability of these devices and provided additional technical data that should be of considerable value in perfecting their design.

Tests were also made to determine the practicability of determining the yield of a nuclear explosion by means of a simple type of pressure gauge at a known distance from the explosion. The technical data obtained indicated that the method is feasible within a reasonable degree of accuracy. Data necessary for the development of an improved type of gauge was obtained.

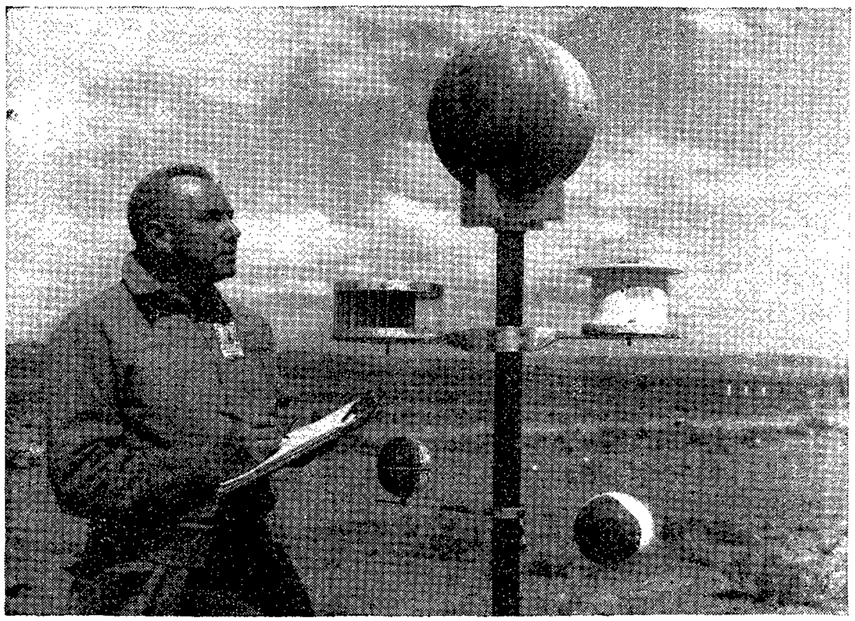

Figure 13.—Inspection—A project officer, following the blast, inspects ground zero locator devices which would have been used by Civil Defense to determine the location of a nuclear burst. The coated spheres were scorched by thermal radiation.

Exposure of Foods and Foodstuffs to Nuclear Explosions (Project 32)

Project 32 consisted of 5 projects, namely the effects of a nuclear explosion on bulk staples, canned foods, meats and meat products, semiperishable foods and packaging, and frozen foods. A sixth project, canned and bottled beverages, was added to the original plan.

The testing of foodstuffs, under field conditions, to nuclear radiation was a joint effort of the food and packaging industry and the Government. The Food and Drug Administration had the original responsibility for setting up the tests, and collaborated with the Department of Agriculture and industry test participants in determining the categories of food which were to be exposed. The test was sponsored by the Federal Civil Defense Administration.

Categories based on a survey of foods most frequently used in the American diet, and foods used in the intermediate manufacture of finished products, were defined as follows:

(a) Staples such as flour and sugar; (b) semiperishables such as lard and butter, ham and bacon, apples, onions and potatoes; (c) fresh meats under usual commercial refrigerated conditions; (d) frozen foods under like

conditions; (e) heat-processed foods in cans and glass, and (f) canned and bottled beverages such as soft drinks.

The heat-processed foods encompassed approximately 60 kinds, in different size packages and a variety of canning procedures. These ranged from soups and vegetables to baby food and beef stew. One industry participant carried out an extensive study on a number of other enclosures, including wood, paper, many kinds of plastics, cellophane and aluminum wrap. The overall volume of this combined food exposure was about 15 tons, half of it being of the canned type.

The projects are described as follows:

In each of the categories samples were exposed at 3 distances from ground zero. Two stations were close enough to receive heavy exposures of nuclear and thermal radiation and high blast overpressures. The third station was in the fallout area, probably beyond the range of the initial effects. Immediate tests were made for evidence of fallout contamination, induced radioactivity, mechanical or chemical failure of enclosures, and physical or chemical changes in the food.

Bulk Staples

The objective was to study the effects of nuclear explosions on samples of bulk food staples, including the study of induced radioactivity, change in moleculars, the effects of heat and blast on containers and the food itself, and contamination problems resulting from radioactive fallout.

About 25 staple foods in retail packages and in small replicas of wholesale packages were exposed. Bulk lots—100 pounds or more—of several staples also were included and subsequently will be used in a ration for animal-feeding experiments. Toxicity and nutritional adequacy will be evaluated in a series of animal feeding studies subsequently, tests will be made to determine trace qualities of radioactive elements and other common elementary constituents.

Canned Foods

The objective was to test the effects of nuclear explosions on a wide variety of heat-sterilized canned foods in both tin and glass containers.

Representative vegetables, fruits, fish, meats, specialties, soups, and baby foods packed in tin and glass containers were exposed both in and out of shipping cases under conditions representative of normal handling in storage, retail sales, in the home, and in emergency shelters. Efforts will be made to develop public understanding of the facts emerging from these tests concerning the suitability of the foods for use and any preferable conditions of storage.

Meat and Meat Products

The objective was to test the effects of nuclear explosions on typical meat and meat food products and materials used in the preparation of meat food products.

The fresh meats were exposed under conditions simulating normal refrigeration practices. Taste panels have tested the exposed products for deterioration and palatability. Effects on vitamin content of products will be determined later.

Semiperishable Foods and Packaging

The objective was to test the effects of nuclear explosions on a variety of semiperishable packaged foods, such as potatoes, onions, apples, raisins, and dry beans, and on various types of packaging materials.

Semiperishable foods, packaged in different types of wholesale and retail sized containers in common use were exposed under conditions simulating normal commercial practice. Following exposure, produce items were stored for periodic examination for exposure injury, decay, and physiological change.

Frozen Foods

The objective was to study the effects of nuclear explosions on typical frozen foods.

Samples were placed in typical home and commercial freezer cabinets, using the structures of other CETG projects. Tests have been made evaluating the samples for flavor, appearance, and texture.

Test Philosophy

There are three ways in which these tests on foods may be expected to provide important information:

1. *An evaluation of the most critical conditions under which food may be found in relation to the explosion of a nuclear weapon.*—By critical condition is meant exposure on the fringe or within the area of total physical destruction. For orientation, this would be a nuclear device similar to the one tested in Nevada with approximately a 30 kiloton yield. For such a yield, the zone of total destruction would be approximately $1\frac{1}{10}$ miles in diameter. In this area practically all structures would be destroyed except steel and reinforced steel and concrete buildings. Under these conditions it would be possible for considerable amounts of foodstuff to be recovered. However, this food would have been subjected to a very high radiation flux, possibly heat, and certainly a large overpressure which may be expected to

cause surge-breakage in glass, failure of steel cans, tearing, rending, and crushing of more fragile packaging. These areas of possible recoverable food might prove to be very important in cases where communications are completely disrupted and the transportation of food from elsewhere restricted.

The other reasons for making such critical exposures would be in the nature of orientation. For example, if the exposure tests showed that many of the critically exposed foods would be safe for use, then all other exposures of a less critical nature would not have to be examined so closely.

On the Nevada Test Site there were no structures within the quarter-mile fringe which resembled buildings of the type discussed. The procedure was adopted of burying the food samples in shallow trenches covered lightly with 1 or 2 inches of soil. This arrangement allowed the foods to be exposed to the maximum irradiation by gamma rays, protons, and neutrons and to the maximum transmission of the pressure wave with shielding from the destructive heat flash which might also have been expected in a structure.

Thus, while burying the food might not appear completely realistic, it is believed it simulates actual comparable storage conditions.

2. *Practical Situations.*—In Operation Cue, at distances of from 1 to 3 miles from ground zero, there were extensive home and industrial structures. In these were placed a variety of foodstuffs. They were put on shelves, stored in cartons in basements, or placed on large shelves such as might be found in grocery stores. This kind of procedure was expected to give desired information quickly. Except for certain special considerations, it is believed that the damage incurred would not be particularly peculiar to atomic bombs and would be readily referrable to the experiences of any Food and Drug inspector in investigating other natural disasters such as the Texas City explosion, hurricane damage, and fire.

3. *Fallout Situations.*—At considerable distances from the explosion of an atomic bomb, it may be expected that radioactive dust will fall and cause many different contamination situations: For example, contamination of a burlap sack containing potatoes, a carton of breakfast food, or a crate of apples. The evaluation of this type of contamination is intimately associated with the wrapping of the product and the way it is shielded by a structure. To create a critical fallout situation, products were deliberately exposed in the open without shielding in the hope they would catch the maximum amount of dust and serve as practice objects to determine how serious contamination could be, and how difficult the clean-up would be.

There is a difference between radioactive contamination due to dust and radioactivity induced inside the food due to irradiaton by neutrons. The latter wll occur only where the food has been as close as about 1,000 feet to 1,200 feet to ground zero. Within this distance there is a high flux of

neutrons, and when they penetrate the food they produce radioactive atoms by transmutation. Some of the atoms which are affected are: Sodium, potassium, calcium, chlorine, phosphorus, sulphur, and possibly tin and zinc. This type of radioactivity cannot be brushed off, but is intrinsic. It is necessary to study these critically exposed foods to determine how radioactive they are, what the radioactive elements are, and the biological significance of this radiation in relation to possible health hazards.

Evaluation of Effects

Many of the effects on foods, that may have occurred, are still in the process of being determined; therefore, it is possible only to discuss results that can be determined with relatively simple equipment.

1. *Physical Damage.*—Damage to glass and cans such as crushing, tearing, bursting, and perforation by flying missiles. This kind of damage is not peculiar to atomic bombs except that the flying missiles—chiefly glass—travels at such a high rate of speed that they will go through steel cans like bullets. The other peculiarities of atomic damage are the pressure surges which, if a glass container is oriented in the right way, may produce "mouse holes" in the glass or cause certain types of snap-on caps to be momentarily lifted. The more fragile containers, such as paper, wood, and cellophane, would be even more subject to these hazards. From the observations made at these tests, most of the damage was caused by physical displacement. There were relatively few missile perforations or surge-failures of the glass containers.

2. *Organoleptic.*—Many of these effects were studied directly in the field. They involved the usual criteria with which the inspector is familiar and they showed several interesting things. Most of the dried milk had an off-flavor when reconstituted. Some of the beverages had slight off-flavors. There was nothing in these tests which indicated a product would be violently unpalatable.

3. *Induced Radiations.*—There was considerable induced radiation in those foods placed at about 1,200 feet. This irradiation consisted chiefly of activity in the glass and somewhat less in the steel. It is believed that the glass was radioactive because of its sodium content and the steel possibly from its tin liners. This radioactivity deteriorated very rapidly so that within several days "hot" glass bottles would have cooled so far that its activity could hardly be determined with a survey instrument. In contrast, metal cans which were not as highly radioactive initially did maintain this activity much longer than glass. Another important fact was that if the container was radioactive, this would not necessarily be conveyed to the contents. This was shown in certain experiments where beverages removed from the glass bottles were relatively inactive as compared with

the glass bottle and could safely be consumed. Many of the foods, of course, were radioactive and in this category the most important ones were the seafoods and the dairy products. These were still measurably radioactive after a month and it is believed that the chief element involved here was probably phosphorus.

A side experiment was conducted in which about 20 elements which are significant in food, either as a part of the container or of the food itself, were exposed in 0.5 percent aqueous solution and in the dry form. From this experiment, it is expected that important orientation of the significance of these elements will be found. Thus, for example, since it is known that tin leaches slowly from most can liners into the food, what will be the significance of 10-20 ppm of radioactive tin in the food? If the pure tin salt under the same condition does not become radioactive, then tin need not be considered.

Beside the radioactivity noted in the glass from the quarter mile distance, there was also a "dusky," "smoky" or darkened appearance. This visual evidence of exposure is so clear cut it is certain that glass was critically exposed to neutrons and gamma radiation. In fact, if the glass remains clear, it would be safe even to eat the contents of such a jar immediately, provided it was otherwise physically intact.

4. *Fallout.*—Unfortunately, the samples which were placed in areas where fallout was expected received very little because the atomic cloud passed in other directions. From limited experiments the following conclusions can be drawn: Fallout particles are very difficult to clean off such materials as cloth or burlap. The particles impinge in seams of pasteboard cartons and cellophane wraps and are quite difficult to remove by dry treatment. One of the greatest hazards is to have damp or greasy packages. These will tenaciously hold the radioactive dust and it is practically impossible to clean off. Except in such cases where the wrap is pervious, like burlap, it seems possible that the contents can be saved by removing them from the container. This radioactivity, due to fallout, declines very rapidly within the first few days. However, some persistence was noted; this probably was due to some of the important strontium 90 complexes which have long half-lives and are biologically very significant.

5. *Chemical Changes.*—Nothing positive at the time of this report has been found with respect to chemical changes in the foodstuff. These studies will be in progress for some time.

6. *Nutritional Changes.*—The evaluation of the effect on vitamins is in progress. Two years ago in the Drug Test, vitamin B–12 was shown to deteriorate. It is known from other observations that vitamin E may deteriorate. Determination of other nutritional changes, such as protein inadequacy or degeneration, will require animal experimentation.

7. *Toxicity.*—There is some indication that high radiation flux may cause degeneration in foodstuff which is only suspected from some of the "off" flavors—possibly the formation of amines which might be pharmacologically significant. To this end, the Division of Pharmacology is now conducting 4 animal experiments as follows:

(a) Eight dogs will be fed 1 year on a beef stew that is a standard commercial canned product. The experiment, at present, is set up so that this beef stew will be at least 50–75 percent of the animals' diet. It is expected to point up chiefly toxicity, if present, but may show nutritional inadequacies because the diet is not 100 percent beef stew.

(b) Sixty rats are being fed for 6 months on a standard canned-in-glass baby food consisting of a liver and vegetable puree. The animals start at weaning and are carried through their period of active growth. Since these animals eat only the baby food, it is believed that this experiment may show both a toxic and a nutritional effect if any exists.

(c) Sixty rats will be fed a synthetic diet for their lifetime of about 2 years. This diet will be composed of some of the staples such as flour, peanuts, and corn meal. The animals will eat this diet 100 percent. Here again combinations of nutritional and toxic responses can be expected.

(d) Eight monkeys will receive a supplement of special-pack canned vegetables consisting of potatoes, turnips, carrots, and sweet potatoes. These vegetables are supposed to replace their supplement of fresh greens such as kale. Monkeys are susceptible, as is the human, to the lack of vitamin C, and should this vitamin be destroyed it is possible that we may observe a nutritional effect here.

Tentative Conclusions

The foodstuff exposed at one mile—the distance would be greater in the case of larger bursts—are safe to eat immediately, provided the containers are intact.

At this distance, induced radioactivity is minimal and certainly not, under disaster conditions, anything more than academic.

In foods buried at 1,000 feet, there was considerable radioactivity. However, according to so-called *disaster standards,* these foods could be eaten in 1 day simply because it is less hazardous to eat than to starve. If disaster conditions no longer exist the foods very probably would be removed from the market.

The same general conclusions would apply to drinks. It is important to be able to use drinks immediately, and their wide distribution in a metropolitan area is very important. The amount of induced radioactivity in drinks, except in the containers as noted before, is relatively lower than in foodstuff; furthermore, it will be lower in drinks than in the water originating from a reservoir contaminated with fallout.

Effects of an Atomic Explosion on Group and Family Type Personnel Shelters (Projects 34.1 and 34.3)

This preliminary report covers shelter designs that were tested in Operation Cue to obtain information on effective protection under the following conditions:

a. For families in homes with basements on the outskirts of cities,

b. For families in homes without basements on the outskirts of cities,

c. For industrial, civil defense, or other personnel unable to evacuate because of the nature of their duties.

Results of other shelter tests are still under evaluation and will be the subject of separate releases.

Basement shelters tested were of 3 types: Lean-to, corner room, and shear wall concrete enclosure. The first 2 types were first tested in Operation Doorstep, in 1953.

The fact that the shelters are below ground level, with several feet of earth between the occupants and the burst, means that occupants are given good protection from initial radiation as well as from debris and missiles. In the event of fallout, the belowground location of the shelters may mean as much as 90 percent reduction in the amount of radiation received from outside contamination. This protection can be materially improved by sandbagging.

Figure 14.—The Shelter Wouldn't Go Down—First tested in 1953, this corner-basement-type shelter (left) was placed under a brick house at 4,700 feet in an effort to obtain a maximum debris load. This scene was the result. Records storage equipment, test items, are seen in right foreground.

The shear wall concrete shelters were in the redesigned frame houses at 5,500 feet and 7,800 feet. In the redesign, the pipe columns normally supporting first floor systems were replaced by concrete shear walls. By incorporating end walls, adding a wall next to the stairway, and a concrete slab roof for the shear walls a very strong shelter was formed that would provide excellent protection at the overpressure range at which it was tested (4 pounds per square inch).

FCDA has consistently stressed the need for an escape route from basements in case of fire. The basement shelters are recommended with the understanding that there are adequate means of escaping from the basement should the house burn. An escape route should minimize danger of entrapment by debris.

For families in homes without basements, a reinforced concrete shelter was designed around the bathroom area of the single-story frame ramblers exposed during Operation Cue. The shelter was closed by means of a heavy wooden blast door, and a heavy blast shutter.

In spite of complete destruction of the rambler at the 4,700-foot range, the bathroom shelter remained intact. The amount of blast entering the shelter was inconsequential, and occupants would not have been harmed by either blast or missiles.

A shelter designed to accommodate 30 persons was exposed at a distance of 1,250 feet from ground zero, at an overpressure range of approximately 100 psi. The shelter is adaptable for greater numbers by increasing the

Figure 15.—Shelter in a Desert—It was difficult for test invitees to realize that much of the flat, sandy desert in Yucca Flat had been moved around considerably during pretest construction. Here workmen are building a 40-man shelter at 1,050 feet from the shot tower.

dimension of length. It was designed for situations that may be found in many industrial plants, where personnel must remain behind to perform closedown operations to prevent severe damage to equipment.

The shelter performed satisfactorily, preventing the entry of blast without suffering structural damage.

Effects of an Atomic Explosion on Electric Utilities (Project 35.1)

The ability of electric supply systems to withstand the effects of an atomic explosion, and the related problem of rapid restoration of electric service to survival areas, are of serious concern to both the Federal Civil Defense Administration and the electric utility companies in the United States. Because of the lack of information on this subject, the Edison Electric Institute, a nationwide association of investor-owned electric utility companies, agreed to participate in the project.

While there is a limited amount of data available on effects of World War II atomic explosions on electric supply systems of Japan, there is no published information on the effect of such an explosion on typical U. S. systems which are generally different in construction from those in Japan. The objectives of Project 35.1 were to determine the following:

1. The degree and nature of damage caused by an atomic explosion to transmission lines, transformers, substations, and other equipment beyond the area of total destruction.
2. The extent to which radioactivity may affect repairs in the area.
3. The median survival range of equipment with respect to blast pressure, thermal energy, and nuclear radiation.
4. The relative ability of the individual parts of each component to withstand the effects of an atomic explosion.
5. The nature of repairs and rehabilitation required to restore electric service to areas subjected to an atomic explosion.
6. The ability of the electric supply system, in comparison with the industrial plants, commercial and residential communities it serves, to withstand the effects of an atomic explosion.

Installations

The project construction consisted of duplicate installations, one at 4,700 feet and another at 10,500 feet from ground zero. Each installation was made up of a 69 KV transmission line, an outdoor substation, and 11 KV and 4 KV distribution circuits. These installations were representative of those serving an urban community. The 69 KV transmission line, 69 KV

switch rack with oil circuit breakers, and power transformer were typical of equipment which might supply large industrial plants.

Distribution lines in each installation consisted of about one-half mile of typical wood-pole construction, oriented radially and transversely to the line of blast. In addition, 25-foot, full-length creosote-treated wood poles without equipment were set 5 feet in the ground at 5 locations, which ranged from 2,750 feet to 4,150 feet from ground zero.

Test Damage

Damage to the electric system at the 4,700-foot line was moderate. The type of damage appeared similar to that caused by severe windstorms and was due to the blast and missiles, rather than to thermal or radiation effects.

One suspension-type transmission tower had collapsed and was lying on the ground.

The substation had survived the blast with minor damage to the essential components. The metal cubicle housing meters and relays was heavily damaged. This cubicle and contents are not essential to emergency operation of the system. The 4 KV regulators had been shifted on the concrete pad separating electrical connections to the bus.

The substation was in sufficiently sound condition to permit re-energizing on a nonautomatic basis.

The distribution wood-pole line would have required considerable rebuilding. Four out of the 15 poles had been broken, several distribution transformers had fallen, and secondary wires and service drops were down. This damage was of the type that could be repaired in a reasonably short time with materials normally carried in stock by electric utility companies.

All ornamental type street light standards were undamaged; however, the luminares were all broken off by swinging conductors, and were lying on the ground underneath. The wood pole-mounted mast-arm type units were undamaged except for a moderate bending of the mast arm. The streamlined elliptical luminares were all intact.

Detailed Results

In the substation at 4,700 feet, the steel dead end structure supporting the 69 KV insulators, disconnects, and buses received minor structural damage. Two leg angles were slightly buckled at a point 3 feet above the foundation where several unused bolt holes were located.

The 73 KV oil circuit breaker remained in the closed position, withstood a 30 KV high potential test to ground, was operated both manually and electrically, and was undamaged.

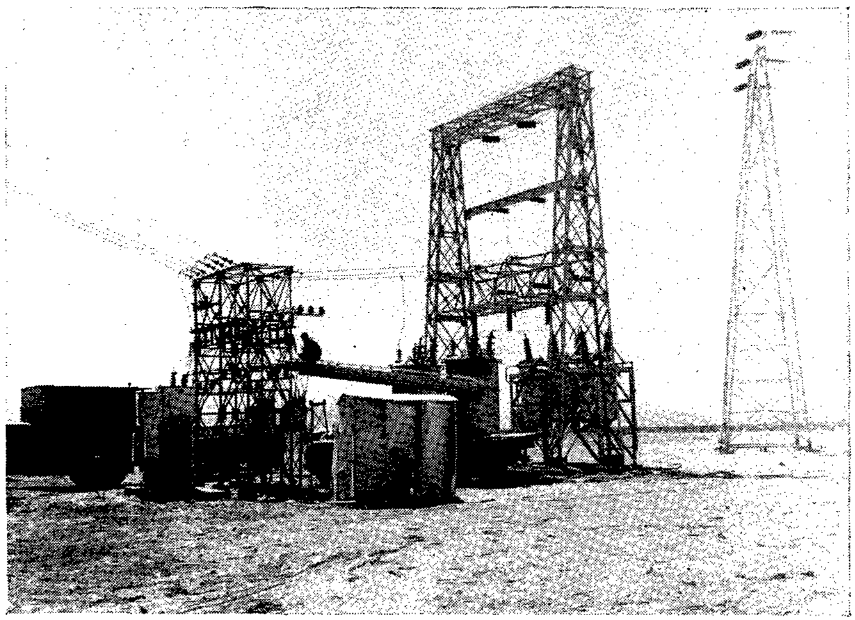

Figure 16.—Survival—Electric power installations at the 4,700-foot range, duplicated at the 10,500-foot line, survived with minor damage. The substation was in sufficiently sound condition to permit reenergizing on a nonautomatic basis.

All insulators, disconnect switches, buses, and hardware were tested identically to preshot tests and were undamaged.

Two 1500 KVA, 69/11 KV transformers were undamaged and unmoved on the foundation pad. They withstood a 30 KV high potential test to ground, the turn ratio between windings tested satisfactorily, and they meggered the same as preshot values. The paint on the side of the case facing the blast was slightly blistered. Neither the temperature nor the oil level gauges were damaged.

The steel rack with the 4 KV equipment including 7.5 KV 400-ampere disconnect switches, two 7.5 KV 800-ampere circuit breakers, and associated buses was undamaged, as determined by observation and repeated high potential tests, megger, and operational tests identical to preshot tests.

The two 4 KV, 200-ampere induction regulators were shifted on the foundation pad sufficiently to break electrical connections to the bus. In addition the square flat surfaced housing at the top of 1 regulator was dished on all 4 faces. The flat-faced temperature gauge glass was broken, but the cylindrical oil level gauge was not broken.

The regulators were tested and found to be electrically operative, but the raise and lower mechanism was temporarily jammed mechanically. After approximately four operations of the raise and lower contactor the mechanism was moving freely and was operating efficiently.

The 3-compartment metal cubicle housing meters, batteries, and instruments, was severely damaged. The foundation pad to which this structure was bolted was noticeably tilted.

The battery cells were completely destroyed. Several glass cells were broken, acid was spilled over the ground, and most plates were damaged beyond repair.

The relays, instruments, and meters were tested identically to preshot tests, and were undamaged except for a broken cover glass on the recording wattmeter.

The distribution system at 4,700 feet sustained light to moderate damage. Out of 14 pole positions 5 received no damage, and 4 were down. No 11 KV metal insulator pins failed, and except for down poles, the 11 KV circuit could have been re-energized.

All primary conductors, both aluminum and copper, and the aerial cable, were unbroken even in the area of heavy damage to crossarms and poles. All pole anchors and guys remained intact. The two 10 KVA transformers installed on a line crossarm and connected in open delta were not displaced although subject to direct effects of the blast. The 2 pothead installations, located on poles that were broken, were unharmed. The risers were bent, but not broken. All arresters and fused cutouts were unharmed and firmly in place where arms were not broken.

Of the 5 poles without equipment, located along the blast line, the 2 nearest ground zero at 2,750 feet and 3,050 feet, were broken off at the ground line.

Slight charring was noted on these poles, but to a lesser degree than on the poles at the 4,700-foot line.

At the 10,500-foot installation the electric system was intact with no damage except for a slight denting of a panel door on the relay and meter cubicle.

Conclusions

Radiation and thermal energy caused no significant damage to the structures and electrical equipment at either the 4,700-foot or 10,500-foot line. Blast damage occurred only at the 4,700-foot line.

The damage to the electrical supply system components was largely confined to the transmission and distribution circuits, and was of a nature that is quickly and easily repaired. It is significant that the major substation and switching yard equipment, which is the most difficult and time consuming to repair, suffered relatively little damage in an area where typical urban residential dwellings were destroyed.

No significant damage to electrical equipment such as poles, insulators, bushings, windings, instruments, and mechanisms occurred from thermal radiation at the 4,700-foot and 10,500-foot test lines.

The comparative strength of the dead end tower, which withstood the blast, to that of the suspension tower which failed, is indicated by their respective weights, of 3,185 pounds and 1,852 pounds. In consideration of the fact that the suspension tower under test was designed for light wind and ice loadings, it should be noted that many utilities throughout the United States have much heavier suspension tower construction that might well have withstood the blast. Data available in this report should be a suitable guide in making this determination.

The substation equipment withstood the blast best of all the electrical components. It remained entirely operative on a manual basis and by the replacement of the station battery it would have been operative on a fully automatic basis. There is reasonable evidence to believe that the survival range of the substation would be considerably forward of the 4,700-foot area.

Three and possibly 4 poles were down because of the resistance of the aerial cable to blast and the only other 2 seriously damaged poles were struck by missiles. It is concluded that open 4 KV wire construction under these particular test conditions would have suffered only minor damage, and that caused by missiles. Aerial cable oriented radially to the blast withstood the effects in the blast zone tested.

The steel pin construction definitely withstood the blast pressures better than the wood pin insulator support.

From the relative blast effects on houses and distribution circuits it is reasonable to assume that the distribution construction would have successfully withstood blast effects at approximately 6,500 feet from ground zero under the type of test conditions existing at the Nevada Test Site. The survival range of the transmission line is considerably forward of the 10,500-foot area from ground zero.

Effects of a Nuclear Explosion on Communications Equipment (Project 35.2)

Without communications civil defense cannot operate or fulfill its responsibility for warning and informing the public. Therefore, it was important to evaluate the extent of damage on 2-way mobile radio equipment, antennas and towers, vacuum tubes, telephone exchanges, standard AM broadcast stations, home receivers, and similar communication elements. Information on the nature and extent of needed repairs after the blast outside the zone of total destruction also was considered very useful to civil defense planners.

The manufacturers of communications equipment have recognized the importance to the national defense of effects of a nuclear explosion on commercial communications equipment. As a public service, the Board of Directors of Radio-Electronics-Television Manufacturers Association (RETMA) accepted an invitation from the Federal Civil Defense Administration to participate in Project 35.2 at the Nevada Test Site.

Objectives

The tests were designed to provide civil defense planners with qualitative damage data. The 150 or more products contributed by manufacturers for exposure established certain significant facts.

The tests were planned to reveal the type of mechanical design which would best withstand a nuclear explosion and to disclose weak spots which might be strengthened without substantial increase in cost to the producer. The tests also were designed to show users the types of building construction and locations, within or near buildings, which are preferred for survival of communications equipment.

Although military communications equipment has been given such tests, it generally has been designed for higher cost and more rigorous service. In areas where military and civilian equipment tests may be safely compared, no substantial differences in results or conclusions have been noted.

Results and Conclusions

FOR CIVIL DEFENSE PLANNERS

The following statements derived from the results of the test are offered to supplement the FCDA's published chart of "Estimated Blast Damage From Nuclear Explosions":

Zone of B Damage.—Communications equipment moderately damaged, generally usable with minor on-site servicing.

Home receivers (TV and broadcast) generally usable without servicing, but most TV receiving antennas damaged beyond use.

Some towers for radio transmitting antennas damaged beyond use, more sturdy towers may be usable.

Zone of C Damage.—All communications equipment usable, generally without servicing. Towers for radio transmitting antennas not damaged.

Zone of D Damage.—All communications equipment usable with substantially no servicing. Towers for radio transmitting antennas not damaged.

Extrapolation of data to Zone of A Damage is considered too speculative for inclusion.

For Product Designers

Mechanical failures were very few. Scuffs, scratches, minor surface scorching gouges, and dents are excluded from consideration since their presence results in no impairment of service.

Plastic cases and knobs on portable radio receivers, TV sets and telephone handsets were severely chipped and cracked in a few cases when these unattached receivers became missiles or were subjected to falling structures. In no case was performance impaired appreciably. It is doubtful whether the plastic cases could be made sturdier without increasing cost. If desired, the test conditions can be successfully simulated in the factory laboratory by simple drop and impact tests.

Plastic-covered coaxial cable and outdoor telephone wire, used as a service drop at the entrance to a building, were noted to have a small fraction of their surfaces covered with a carbon deposit resulting from flash burning of the insulation. It is certain that insulation resistance would have been impaired closer to ground zero. This adverse reaction due to thermal radiation should be considered by industry for quantitative investigation in the laboratory. Also, a microphone screen of nylon appeared to have melted in Zone B.

Whip antennas under blast conditions have a tendency to bend or break off at the point of attachment to the car body. Manufacturers may be able to make this section stronger without increased cost. However, a more practical solution lies in maintaining spare whip antenna assemblies for each fleet of cars equipped with mobile radio.

TV receiving antennas generally failed in Zone B due to bending of elements and structural collapse, about as they would do in a hurricane. It is doubtful if manufacturers could design TV receiving antennas to withstand such forces without substantial increase in cost.

The failure of the 120-foot unguyed antenna tower 40 feet above the ground (4,700 feet from ground zero) disclosed an unusual design problem which unfortunately is not susceptible to laboratory investigation. All 3 of the steel tubes "ripped" just above arc welds at a step-taper transition. There was no evidence of elongation, bending, or folding. The rips had more of the appearance of fatigue failure than rupture from any other familiar cause; yet there was no evidence that metal fatigue actually occurred.

For Users

In the home and in the car, battery-operated receivers are desirable for emergencies when power lines fail.

Since communications are so vital in emergencies such as a nuclear explosion, those who plan new buildings for broadcast transmitter stations

or mobile radio base stations should consider the sturdiness of the building and the orientation of the building and its rooms with respect to a probable target point in the vicinity. The findings of Project 31.1 of Operation Teapot with respect to building comparisons are pertinent. The single-story reinforced masonry block, basementless type of house and the single-story, precast concrete slab, basementless design of residence gave fair protection to communications equipment therein. The 2-story, brick veneer, masonry house with basement and the single-story, frame, basementless house gave little or no protection to communications equipment therein. The collapse of these structures damaged the communications equipment in some cases. If such equipment is housed in a structure which does not collapse, there is a definite advantage in having an inside bearing wall plus the building wall between the equipment and ground zero.

However, there should be large-area windows facing both toward and away from ground zero which will blow in or out and thus provide fast pressure equalization; also there should be open doorways or equivalent between inside rooms to provide prompt pressure equalization between rooms and thus avoid collapse of the inside bearing walls. Of course, an underground transmitter building with adequate roof strength would be safer than a surface structure.

In this test 60-cycle power-supply failure was the cause of the outage of the broadcast transmitter station. Greater protection may be provided by using underground service wires to the building. If a pole line leans with the blast, the main power lines may be intact while the overhead customer-service lines are snapped. In this test, such conditions prevented the AM broadcast transmitter from coming back on the air 3 minutes after the blast. Additional protection may be obtained by utilizing a gas-engine-driven generator or equivalent as an emergency power supply. Such a machine should be placed in a well-protected location.

Of about equal failure probability for a broadcast transmitter is loss of telephone-line or radio-link facilities for programing the station. However, many of the emergency functions of a broadcast station may be carried on if minimum studio and control room facilities—at least an announcer's microphone and tape reproducer—are located at the transmitter site. A complete spare studio-to-transmitter radio link is desirable but costly. The use of a tape recorder is very convenient to repetitively transmit important announcements to the public, as was done in this test.

Availability of critical spare parts and batteries is important.

The antenna tower is probably the third weakest link in the chain of reliability for radio transmitting systems, and hence tower strength is not the place to economize if relative ability to withstand the effects of nuclear

explosions is desired. These tests did not provide conclusive data for a choice between guyed and unguyed towers.

Transmitter buildings, antenna towers, and guy wires should be located to minimize the likelihood of other structures or pole lines falling on them in case of nuclear explosion; also consideration should be given to the avoidance of missiles, such as pole-mounted distribution transformers, which might be moving away from the target area.

The Siren Test (Project 35.2a)

Two sirens, rated 115 db and 110 db, were exposed at 4,700 feet and 2 similar units at 10,500 feet from ground zero.

The 115 db siren at each location was installed on a 30-foot steel tower, which was bolted to steel anchor bolts embedded in a concrete foundation. Each foundation weighed about 3 tons. The associated siren was operated by a 3-phase, 220-volt motor rated at 10 horsepower. The control box for the motor, made of 14-gauge steel, was located 4 feet above the base foundation. Controls consisted of a magnetic starter, circuit breaker, and pushbutton, plus all wiring necessary to operate the siren.

The 110 db siren at each location was mounted on anchor bolts embedded in a concrete foundation weighing about 2 tons. A fused magnetic starter and pushbutton control were attached to the shroud surrounding each of the sirens. The driving motor was rated at 7½ horsepower, 3-phase, 220 volts.

After the explosion it was observed at the 4,700-foot line that the ground level siren received a slight bending on the top panel of its shroud. The exposed part of the electric cable was discolored by thermal radiation. The siren on the 30-foot tower received inconsequential missile scratching. The control panel door was slightly indented, but opened satisfactorily.

At 10,500 feet the damage was very slight.

All sirens were operated successfully without need for repairs.

In planning for a siren warning system, it is desirable to locate sirens away from structures which may collapse under them or fall on them. Sirens placed on top of buildings may be inaccessible for repairs after a nuclear explosion due to a hazardous condition of the building. Sturdy sirens and strong bases are also important. Postexplosion availability of 3-phase, 220-volt power is another important consideration in the location of sirens.

Effects of a Nuclear Explosion on Industrial and Domestic Gas Storage and Distribution (Liquefied Petroleum Gas) (Project 35.4a)

Objectives

The objectives of the tests made under this project, sponsored jointly by the Liquefied Petroleum Gas Association and FCDA, were to determine the effect of a nuclear explosion on LP–Gas containers and systems of the type normally found in the home, at the storage and cylinder filling plant, and at the industrial and utility plant, as well as to establish the reliance which might be placed on LP–Gas to serve as an emergency fuel after such an explosion.

Test Installations

Three types of LP–Gas containers and systems were exposed at 4 different distances from ground zero. These included dual 100-lb. cylinder systems with automatic change-over, 500-gallon domestic or small commercial tanks, and a complete 18,000-gallon bulk storage plant. Although for this test the tank was piped and installed as a cylinder filling plant, it is typical of thousands of LP–Gas bulk, industrial, and utility plants.

The bulk plant, consisting of a storage tank containing 15,400 gallons of propane weighing over 33 tons; pump; a compressor; a cylinder filling building; a cylinder dock; all necessary valves, fittings, hose, accessories, and interconnecting piping, was located at a point 4,700 feet from ground zero.

Eight domestic type installations, each consisting of two ICC cylinders of 100 lb. LP–Gas capacity, were installed at various distances from ground zero. To simulate normal usage conditions 1 cylinder in each installation was filled to capacity, the other partially filled. Two such installations were made 1,840 feet from ground zero, 1 on each side of a concrete simulated house wall or foundation parallel to the blast line. Two similar installations were made at the 2,750-foot line. Additional cylinder system installations of this type were made at existing test houses; 2 at the 4,700-foot line and 2 at the 10,500-foot line.

Bulk systems of 500-gallon capacity, each containing about 200 gallons of LP–Gas, were located at the 1,840, 2,750, 4,700, and 10,500-foot lines. These tanks were equipped with representative sets of fittings for the servicing and operation of the system. All tanks were equipped with legs which rested on concrete bases and were provided with either copper tubing or steel pipe service lines.

Test Observations and Results

After exposure to a nuclear weapon explosion with a yield of 30 to 35 kilotons (KT) from a 500-foot tower, the approximate overpressures at the test lines were as follows: 1,840 feet—23 psi, 2,750 feet—10 psi, 4,700 feet—5 psi, and 10,500 feet—2 psi.

Examination of the bulk storage plant revealed the following conditions:

(1) The 18,000-gallon tank, valves, and piping survived with only superficial damage and was operable immediately. No leaks were detected.

(2) The transfer facilities including LP–Gas pump, compressor, and piping survived without damage.

(3) The cylinder filling building was demolished and scattered over a wide area. The weighing scales were unusable. The cylinder filling manifold was pulled loose from its supports and the liquid LP–Gas line which served it was severed, although the manifold was otherwise undamaged.

The dual cylinder installations at 1,840 feet suffered the most damage as regulators were torn loose from their mountings and cylinders displaced—one coming to rest nearly 2,000 feet from its original location. It was badly dented, but otherwise sound. The components, though separated, were, for the most part, salvageable and usable. There was less damage at 2,750 feet and though the components of the system were separated from

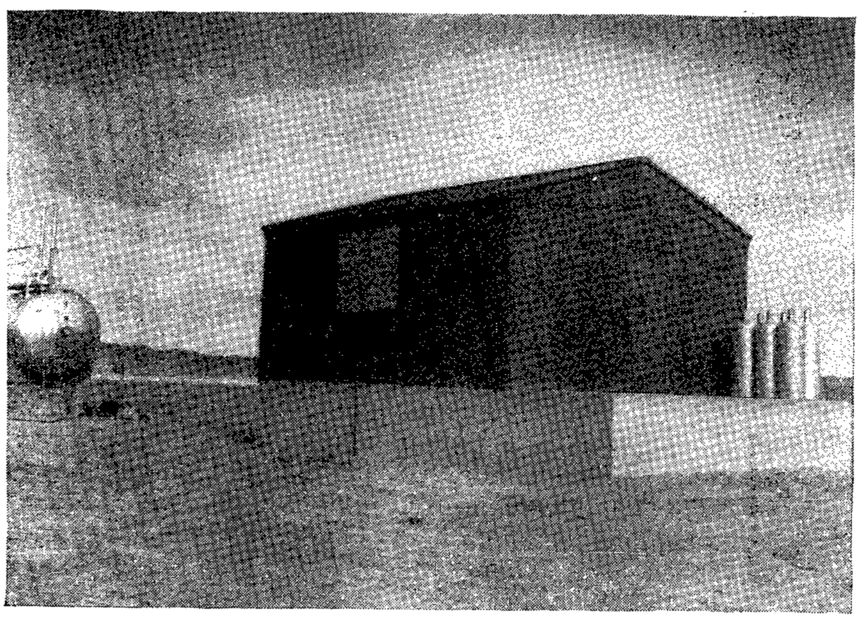

Figure 17.—Bulk Storage Plant (Before)—A liquefied petroleum cylinder-filing plant was constructed at the 4,700-foot line. At the left is seen a portion of an 18,000-gallon bulk storage container which held propane at the time of explosion.

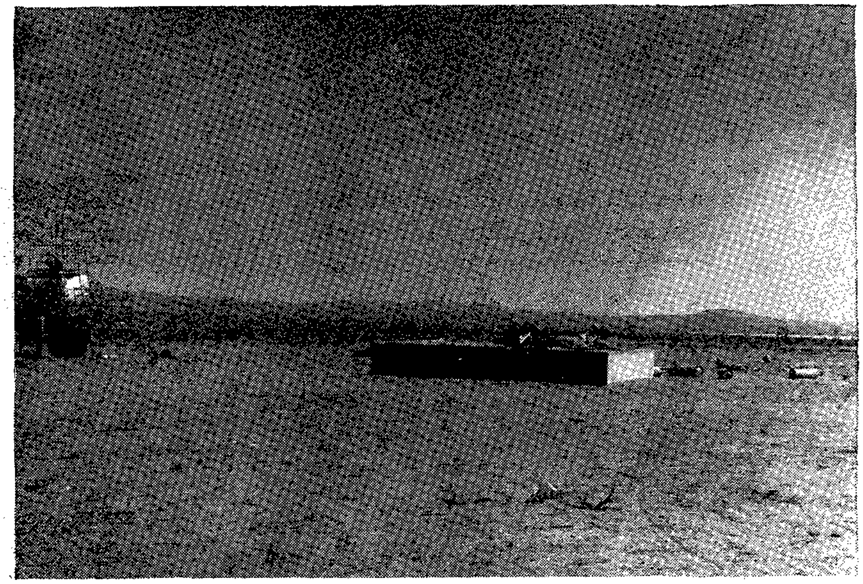

Figure 18.—Bulk Storage Plant (After)—It came as no great surprise that the cylinder-filling plant building disappeared in the atomic blast, but the filling manifold in its interior could readily have been placed in service. The bulk storage cylinder, at left, had no superficial damage.

each other, they could be made operable. The dual cylinder installations at 4,700 feet were mostly damaged by missiles and falling debris from the houses. The component parts, except for the copper tubing, suffered little damage and were usable. There was no damage or dislocation to units at 10,500 feet. Of 25 cylinders, 2 had their cylinder valves sheared off by striking another hard object or by missiles and 1 received a very small pinhole puncture from impact with a small sharp object.

The 500-gallon LP-Gas bulk tanks suffered little damage. The tank at 1,840 feet was found over 700 feet from its original location where it landed after bouncing end over end. Though missile damage was apparent in the end of the tank facing ground zero, it was largely superficial and its strength or serviceability was not impaired. The filler valve was damaged but the internal check valve operated to close the opening and protect the contents of tank. At 2,750 feet the 500-gallon bulk tank was turned end-for-end, rolled over and moved about 5 feet back. The fittings, protective hood, and gas contents were intact—it was flowing gas but the service valve was shut off at R+2 hours. One of the 500-gallon tanks at 4,700 feet, which was installed broadside to blast, rolled over with no damage. All other 500-gallon tanks at 4,700 feet and 10,500 feet were unmoved and undamaged, including the tanks at the houses which were piped for gas service.

Conclusions and Recommendations

It was determined that a nuclear explosion of this magnitude will disrupt LP-Gas service in the close-in area, where such service is by dual cylinder systems and 500-gallon bulk tanks, up to at least 4,700 feet from ground zero. However, most of the equipment—tanks, valves, and regulators—is salvageable, even at 1,840 feet from ground zero. Thus, where the house is standing—even though badly damaged inside—the LP-Gas system may be presumed to be intact and where the house is demolished much of the LP-Gas equipment may be salvaged for use when the cylinder valve has been closed previous to the explosion—needing in most cases only copper tubing, wrench, and flaring tool to resume gas service. Of major importance is the fact that the large volume storage tank with its attendant piping, valves, and transfer facilities was not damaged when located at 4,700 feet from ground zero. The cylinder filling building and facilities were demolished. However, emergency cylinder filling could be resumed on short notice.

It is concluded that LP-Gas equipment has proved to be very rugged except for the copper tubing connections, and that disruption of LP-Gas service will be localized—perhaps negligible. It is further concluded that reliance may be placed on LP-Gas to serve as an emergency fuel in the event of an atomic attack.

The project report concludes with the recommendations that:

(1) The LP-Gas bulk dealer maintain an ample inventory of copper tubing and spare regulators—some of which is kept (along with flaring tools) in a "protected" place—preferably belowground.

(2) In the event of an alert or attack warning, the LP-Gas bulk dealer shut off all valves at the storage tank.

(3) In the event of an alert or attack warning, the LP-Gas user shut off the gas supply valves—at the cylinder or at the bulk tank as the case may be.

(4) The LP-Gas bulk dealer keep the valve protecting cap on all cylinders which are not actually connected for use.

Effects of a Nuclear Explosion on Industrial and Domestic Gas Storage and Distribution (Natural and Manufactured Gas) (Project 35.4b)

Objectives

The objectives of Project 35.4b were to determine the effects of a nuclear device, developing ground shock, atmospheric overpressure, and elevated temperature, on typical gas industry—natural and manufactured fuel gas—installations, equipment, and appliances.

It was expected that information would be obtained which would assist in (1) predicting areas and extent of damage; (2) determining the speed and extent of possible repair and rehabilitation measures; (3) formulating practical and feasible means for minimizing damage to existing facilities; and (4) developing criteria for future construction and equipment that would offer maximum resistance to nuclear effects.

In its participation in the project, the American Gas Association also had as an objective the preparation of a manual for distribution within the gas industry, indicating the areas, extent, and types of expected damage and the possibility of repairs, and giving recommendations for types of construction and equipment that would minimize such damage.

Installations

Underground installations were made at 1,470 feet and 4,700 feet from ground zero, respectively. They included "H"-assemblies of 6-inch pipe, valve pits with valves and projecting piping, buried valves with protective casings, and street regulator vaults. In addition, a parkway regulator vault with gauge box and oil seal was located 4,700 feet from ground zero.

Service piping from an underground main to basementless houses at 4,700 feet and 10,500 feet were tested. The service pipes—steel, copper, and plastic—were connected to a 20-foot length of 6-inch steel main, parallel to and 20 inches distant from the side wall of each building.

The service pipes rose out of the ground at the side of the house and were connected to residential-type pressure regulators and meters, and then entered the wall of the house about 2 feet above floor level. The steel service line was connected to interior house piping.

Different types of gas appliances—including refrigerators, ranges, water heaters, wall heaters, room heaters, clothes dryers, incinerators, and furnaces—were installed in houses located 4,700, 5,500, 7,800, and 10,500 feet from ground zero. Appliances were connected to house piping in 2 precast concrete houses located at the 4,700-foot and 10,500-foot lines, respectively. The appliances in the latter house were left burning at the time of detonation.

Results and Conclusions

In general, because of their inherent strength and simplicity, and because they are largely underground, natural and manufactured gas piping, equipment, and appliances are relatively resistant to nuclear explosion and will be among the most usable or readily reparable civilian facilities.

A typical underground piping, pipe joints and connections, valves in pits and casings, and regulators in vaults—the pits and vaults having cast iron covers at ground level—at 1,470 feet from ground zero, developed only slight leakage at jute and lead-caulked cast-iron bell-and-spigot joints.

The cast-iron covers were unbroken and slightly displaced. Pressure test risers of ¾-inch and 1½-inch piping were bent over, and two 4-inch vent pipes rising 6 feet above ground were sheared off 9 inches below ground level. At a distance of 1,470 feet from ground zero, surface piping or other structures would be destroyed or badly damaged.

Installations at 4,700 feet including a parkway vault with reinforced steel and aluminum plate covers, an aboveground ventilator-gauge box and an oil-seal pressure-relief assembly developed only slight leakage at caulked cast-iron bell-and-spigot joints. At 4,700 feet underground service piping to houses, aboveground house regulators and meters at the side of houses, and piping in houses were undamaged. At 4,700 feet from ground zero, both underground and aboveground piping and equipment would suffer little if any damage and would remain operable.

Appliances in houses at 4,700 feet from ground zero suffered varying degrees of damage from overpressure, missiles, and structural failure of the houses. Overpressure effects were evident on large panels such as on refrigerators. Except where damaged by failure of house structure, appliances were operable with minor reassembly. None of them moved far enough to be torn loose from the house piping. At 4,700 feet from ground zero, appliances would be usable in houses which did not suffer major structural failure.

Appliances in houses at 10,500 feet from ground zero suffered slight damage and would be immediately usable after relighting the pilot lights.

Recommendations

To minimize the destructive effects of nuclear explosions on gas industry installations, the following recommendations are submitted:

1. Distribution piping, valves, regulators, and control equipment should be installed underground by direct burial, or in pits or vaults not rising above ground level, to minimize blast and overpressure effects which may damage or destroy aboveground structures.

2. Lead-caulked cast-iron bell-and-spigot joints should be clamped, or replaced, to avoid development of leakage resulting from ground shock. Flexibility in the pipeline must be maintained to prevent pipe breakage under ground shock conditions.

Effects of a Nuclear Explosion on Record Storage Equipment and Facilities (Project 35.5)

The object of Project 35.5 was to determine the effects of nuclear explosion on different types of records under varying conditions or protection. This is a part of the vital records protection program which is to

provide business and government with the necessary data to continue effective operations after a disaster.

The National Records Management Council and the Safe Manufacturer's National Association participated in this project. According to the Federal Records Act of 1950, a record is "any paper, book, photograph, motion picture film, microfilm, sound recording, punched card, data processing tape, map, drawing or other document that has been made or received by any department or division of the organization."

The United States in World War II depended almost entirely on evacuation or microfilming of records. The National Records Management Council study of Western European experience in this war highlighted the concern of records management for the effects of rubble from building collapse, and fire and water damage to records after bombing cities.

The detailed analysis of the Hiroshima experience produced no data on "records survival." What happened to safes of the Japanese is known, but no data is available on the material within the safes. With this kind of background, conventional thinking has been largely limited to evacuation and wholesale microfilming of records. In lieu of any official guidance, small business has relied on some kind of protective storage, a safe or insulated file, for key records.

It is only within the last 3 years that vital records protection has grown in stature to a full scale objective program that goes beyond any one method of dispersal, filming, or use of equipment per se. The program for each organization is based on 4 fundamental techniques, designed to meet individual needs:

1. *Identify the key records.*—These are proportionately few and are limited to the vital records needed to resume operations.

2. *Designate the most efficient means by which each record is protected.*—These are 4 key methods of protection:

(*a*) *Evacuation* of vital, but infrequently used, records to secure locations.

(*b*) *"Built-in" dispersal*—the protection automatically afforded where copies are normally distributed and maintained in 2 or more locations.

(c) *"Improvised" dispersal*—the creating or freeing of an additional carbon copy of a vital record that may be sent to a secure records center.

(*d*) *Photo-duplication*—preparing for dispersal a vital record copy by microfilm or by one of the photocopy processes.

All 4 methods are used, the choice being determined by the type of record to be protected and the cost of such protection. The cheapest method is, of course, "built-in" dispersal, because it requires no further creation, processing, or transportation of records. The most expensive method is generally photo-duplication. It is therefore usually limited to vital records that are only available in the original, where the original is needed in the office, and when additional carbon copies cannot be "improvised" readily.

3. *Locate and design a records center* that will maintain securely the vital records identified in Technique No. 1. When the location is properly planned and designed, it ties in with the concept of controlled record keeping for larger organizations. Thus, in addition to vital records protection, the center provides low-cost records storage and prompt reference service for records no longer required in the office. It also eliminates the obsolete method of maintaining duplicate facilities with records being housed in both places (a vital records area and some "basement or attic annex" for office records).

4. *Design and select the equipment* that will secure the records most adequately and efficiently in event of disaster, whether the vital records are in office or storage areas. This is an integral part of the program and ties in directly with the concomitant decisions on which records are vital, what is the total volume of vital records, and where are these key records to be located.

To date, there are valuable research and experience data available to assist both business and government in identifying the vital records (Technique No. 1) and designating the most efficient means by which each vital record is protected (Technique No. 2). Data are also currently available on specifications for protection of records against fire and water. For protection against effects of nuclear explosions, however, there are no current guides in designating records centers and records equipment.

Test Results (Unshielded Equipment)

The principal damage and destruction to record storage equipment and records occurred to those unshielded units located from 500 feet through 4,700 feet from ground zero. Out of a total of 22 units placed within this range only 6 remained. Of those, 4 were usable, even though on some the side exposed to the blast was scarred and damaged. Visual inspection of the records and contents in these units disclosed them to be in excellent condition.

Seven of the 8 units located at the 500-foot and 1,050-foot lines were destroyed. The units were broken into small pieces of metal and scattered about the Test Site. Little of the debris found could be identified.

The eighth unit, a small money chest, was rolled approximately 350 feet from its original position. The exterior handle and the dial were burned and destroyed. The contents were not examined, as access to the unit was impracticable at the Test Site.

There were 5 different types of equipment exposed which constitute 3 different classes as specified by the Underwriters Laboratories, Inc., labels for heat and shock. The interior door panel of a class "B" label unit located 1,270 feet from ground zero was found an estimated 700 feet from

its original position. The sensitized thermal strips were intact and indicated that the interior temperature was in excess of 490° F. after the detonation. The records and valuables could not be found; therefore, contents were assumed to be destroyed.

The 2 exterior panels of a class "C" safe were identified 560 feet southwest of the original location at the 1,840-foot line. An estimated 1,800 feet of 35 mm. motion-picture film was spread across the sand. The reels could not be found and the film was broken, cracked, emulsion scratched, and generally unusable. No attempt was made to restore this film.

The 1,840-foot line was the closest position at which an insulated file was placed. This unit was destroyed as only 2 sides and 2 drawer fronts were found. No records were identified.

The most productive results on unshielded equipment were obtained from those units placed at the 2,250-foot line. Two complete safes, one class "A" and one class "B," were recovered. One unit was inaccessible because of a broken handle. The other unit, weighing in excess of 1,000 pounds, was blown through the air approximately 200 feet and then rolled end over end an additional 350 feet. This tumbling action left tracks in the sand. This safe was usable and access was immediate, even though missiles had left large holes through the steel and insulation. The records in this unit were jumbled, but not damaged.

Uninsulated file cabinets exposed at the 2,750-foot and 3,750-foot lines were scorched and rendered unusable as the drawer fronts were pushed in and jammed against the frames. The majority of the records remained in these units and could be obtained by prying the drawers out of the cabinet.

The records contained in units from the 500-, 1,050-, and 1,270-foot lines are believed to be completely destroyed. The large paper debris is believed to have come from the units at the 1,840 through 3,750-foot lines which were blasted apart. However, no identification was possible nor were they recovered.

Test Results (Shielded Equipment)

Most of the major units of equipment located within 2 structures at 4,700 feet, 1 structure at 5,500 feet, and 2 structures at 10,500 feet from ground zero were unaffected by the explosion. The only damage sustained was to an uninsulated file cabinet located on the second floor of the brick building, and to steel shelving located in the basement of the same building. The file cabinet was unusable due to the debris load. Also, the steel shelving in the basement had the upper 2 shelves jammed down as the result of structure failure. In both cases, the records were recovered with no damage.

Cartons of telegraph paper and tape located behind equipment or in structures at 2,250, 2,750, 3,750, 4,700 and 5,500 feet from ground zero

were recovered only from the 3 farthest ranges. The overall effects upon these items cannot be evaluated at this time, as the recovered paper is being run through Western Union transmitting and receiving equipment.

Conclusions

Preliminary results indicate that most records and records storage equipment would survive a nuclear explosion of the same magnitude as Operation Cue provided they were afforded protection against overpressure and thermal effects. The demonstration of unshielded records storage equipment of all classes showed that overpressures of about 15 psi are the maximum to which a safe or record container can be directly exposed and recovered with the records in good usable condition.

The results indicated that a cinder block wall, similar to that of many industrial shops, when exposed to overpressures of about 8 psi, is converted into missiles and in this case, rendered a standard file cabinet unusable, even though the records could be recovered if the debris load did not destroy the records.

On preliminary analysis at the test site, the possible causes of total destruction of 16 unshielded units are believed to have been (1) high thermal radiation followed very closely by the overpressure blast wave; interior pressure probably caused the equipment to explode when the negative phase of the blast wave passed; or (2) destruction of close-in units could have occurred from the explosive force of accumulated gases from the insulation ignited by the intense heat. These theories are indicated by the pieces of metal found and some recovered units. The metal appears to have been twisted and telescoped with a tearing along the welded bead line. On the recovered units there were holes punched in the surface exposed to the blast.

The residential structures on the 4,700-foot line afforded considerable protection to records storage equipment aboveground despite the collapse of 2 structures. The basements of the brick structure, and frame structure, 4,700 feet from ground zero, gave very good protection to the standard records storage equipment located in these structures.

Along with this, was the general observation that from high tower shots or air bursts of a nuclear device of the Operation Cue size there is little or no cratering effect in the ground. Thus, the mass effect of the earth appears to offer the maximum protection for the storage of vital records. However, in subsurface records storage areas such as basements of structures there could be secondary damage resulting from debris, fire, and water.

Final conclusions and recommendations will be inserted when other data are available, including nuclear and thermal radiation, study of equipment inaccessible at the site due to structure failure, and results of chemical analysis of exposed papers, film, and other records.

Utilization of Trailer Coach Mobile Homes Following Exposure to Nuclear Effects (Project 36.1)—Operational Use of Civil Defense Emergency Vehicles (Project 36.2)

Under Program 36 (Exposure of Mobile Homes and Emergency Vehicles to Nuclear Explosions) two segments of industry—those who manufacture and sell mobile homes and those who manufacture and use emergency vehicles—participated with FCDA in exposing representative samples of their equipment to the effects of a nuclear explosion.

Mobile Homes

Mobile homes (trailer coaches) will be an important resource in the event of a future war. This is especially true if our cities are subjected to attack by thermonuclear weapons, leaving large numbers of people homeless and in need of aid. Many of the facilities which might normally be available to care for the homeless or to serve as medical and feeding centers would be severely damaged or destroyed. Trailer parks and trailer dealers are generally located in the suburbs. Development of information as to the nature of damage which the trailers might sustain under these conditions and evaluation of the repairs necessary to make them usable afterwards becomes important.

Two distances from ground zero (10,500 feet and 15,000 feet) were chosen to simulate low blast-pressure areas which might be expected in suburban zones. Sixteen trailers were exposed.

Emergency Vehicles

Planning for postattack operations by the front line civil defense services is predicated on the dispersal of men and equipment. Areas outside the potential zone of "D" damage have been assumed as "safe dispersal locations." According to present civil defense planning assumptions, it is expected that the "C" zone of blast damage will extend to the city limits of the principal city in the critical target area. This would require that emergency equipment would often be without shelter at its dispersal location in the suburban areas of the target cities. Because of a surprise attack or heavy traffic, it is also expected that some vehicles will be caught at close-in locations.

To show the effects on emergency vehicles and their equipment, 11 test units were placed within the various zones of damage, and beyond in the assumed dispersal area. One was at 1,470 feet, 2 at 4,700 feet, 2 at 10,500 feet, and 6 at 15,000 feet from ground zero.

Kinds of Damage (Mobile Homes Test)

Weights of trailers at the 10,500-foot line ranged from 2,180 pounds to 8,600 pounds; those at the 15,000-foot line from 2,190 pounds to 9,550 pounds. Ten were placed side-on to the explosion, 2 broadside, 2 head-on and 2 faced away.

Figure 19.—Mobile Homes in Position—Sixteen trailer coaches were exposed to nuclear detonation at 10,500 and 15,000 feet from ground zero. Both interiors and exteriors sustained varying degrees of light damage, but there was little serious damage.

In every instance the chassis, subfloor and undercarriage, including tires, were not damaged, even though moved or upset.

Types of damage of exteriors included slight to severe dents, distortions, skin ruptures, bulges, seam ruptures, dishing-in between studs, panels out of channel, and dishing-in of sides, roof, front and rear ends. Damage to some units was negligible.

In trailer interiors little or no glass was found, although numerous windows were broken. Kinds of damage included bulges in ceilings and sides, doors off, panel molding off, light fixtures hanging, walls broken, cabinets torn loose, window frames pulled loose, lavatory torn loose, doors of overhead cabinets down, rear wardrobe style broken or loose, toilet tank broken, drapes and blinds down, and mirrors broken. As in the case of exteriors, damage to some test unit interiors was relatively minor.

Kinds of Damage (Emergency Vehicles Test)

Emergency vehicles exposed included a 1½-ton pickup, a 2-ton cab over, 2½-ton flatbed with earth-boring machine bolted to bed, 3-ton special body, two 1-ton pickups, 1½-ton service truck, 75-foot aerial ladder truck, 1,000 GPM fire pumper, jeep fire truck and a rescue truck (1946 model).

No damage to equipment was reported. Four vehicles were undamaged. Five vehicles had broken windows, doors dished in, or motor hood blown away; all of these, with tools and equipment intact, would have been available for emergency operations. For example, the hood of the ladder truck was slightly dished in, but the aerial ladder was operable.

The truck with the earth-boring machine was overturned, and the machine was knocked loose. Later the vehicle was uprighted and driven away. The operating condition of the machine was not determined.

Only one wheel and part of an axle of the rescue truck, located at the 1,470-foot line, were found after the blast.

Conclusions (Mobile Homes Test)

The damage sustained was comparatively minor in nature. Some coaches sustained more damage than others even though they were at the same pressure area. This was due to the different methods of construction, types of fastenings, gauge and design of die-formed metal, spacing of studding, and the use of different-sized windows. There was little or no glass inside the trailers despite the fact that their windows were broken. This was observed especially when the screen insert wire was on the inside of the window, preventing the glass from flying as missiles into the interior. On the smaller windows screening was even more effective.

All trailers could have been lived in after an emergency by boarding up the windows that were broken, rearranging the furniture, and making temporary repairs to the cabinets and wardrobes. Most plumbing, gas lines, and appliances were in usable condition.

The results indicate that mobile homes could be an appreciable asset to a community as emergency housing in the event of an atomic attack.

Conclusions (Emergency Vehicles Test)

The results of the exposure of emergency vehicles and their equipment emphasized that these vehicles were substantially constructed and the tools and equipment were protected from low-blast effects by the design of the truck body, or were adequately housed in compartments with protective doors.

It is apparent that dispersed vehicles will suffer less damage if they are placed head-on to the blast.

Civil Defense Monitoring Techniques (Project 38.1)

Inasmuch as widespread contamination is associated with fallout from thermonuclear weapons, it has become necessary to reevaluate civil defense monitoring techniques. Under A-bomb attack procedures, considerable emphasis has been placed on the ground monitoring team. While this concept has not changed materially, an additional need now exists for rapid surveys covering relatively great distances.

The objective of Project 38.1 was to develop and demonstrate techniques of radiation monitoring by (a) aerial survey; (b) surveys from rapidly moving vehicles; and (c) ground monitoring, and to correlate the results of the various survey methods.

The operational plan called for simultaneous aerial, automotive, and ground surveys in the fallout areas of 2 shots. On the basis of information received from the Rad-Safe Unit, probable fallout paths were investigated to establish survey ranges which would be accessible for the conduct of field operations. Several ranges were laid out for each shot. The ranges were in the form of a cross with each leg 1 mile in length. To provide greater flexibility, some ranges were set up longer in 1 direction with a cross leg at mile intervals so that any cross could be used, depending on the direction of fallout. Terminals of the 8 patterns laid out were marked by large circles, elevated flags, and white airplane panels for maximum visibility.

The aerial survey pattern was in the form of a cloverleaf. The flight started at a 1,000-foot altitude, and descended after each run to 800, 500, and 200-foot altitudes. The planes, an L–20A used by the military and a Stinson 165 provided by the Nevada Civil Air Patrol, were equipped with altimeters with an accuracy of 20 feet.

The automotive party retraced the range in the opposite direction relative to the initial path in order to average out any error due to time lag of the instrument. In most cases the automotive survey was made at 2 speeds to determine the speed correction factor while making surveys in fields of nonuniform intensities.

To reduce the time the ground personnel spent in radiation fields, a pickup truck was used for transporting the monitor between each $\frac{1}{10}$-mile mark.

Prior to shot day, preliminary runs were made to evaluate the time lag factor for the automotive survey by using a high intensity Cobalt 60 source. The attenuation factors were evaluated for the vehicles used. The evaluation included: (a) a pretest measurement with Cobalt 60 using rate meters only; (b) film badge dosimeter measurements for both pretest and during actual field operations; and (c) rate meter readings both outside and inside the body of the vehicles.

FCDA instruments used were the medium-range survey meter (FCDA Std. Item CD V–710), a gamma-only instrument with a maximum reading of 50 r/hr, and the low-range survey meter (FCDA Std. Item CD V–700), a beta-gamma discriminating instrument reading to 50 mr/hr. AN/PDR–T1B ionization chamber instruments were borrowed from the Rad-Safe organization.

The centerline of fallout for the first shot was about 30 degrees east of north. Since it was not possible to enter the area for 6 hours after the shot because of a second detonation, the intensities had dropped considerably by the time the first survey was run. The following morning the intensities over the survey pattern were so low that it would not have been possible to obtain readings from the air.

The centerline of fallout for the second shot was about 30 degrees west of north. Two of the legs were located in dose rate areas of greater than 10 r/hr, and surveys could not be made on them until the second and third runs when the intensities had been reduced below this value. Again the intensities were so low over the survey pattern the following morning that further surveys would not give significant results.

From a preliminary review of data, it is believed that radiation monitoring during a civil defense emergency by either an aerial survey or from a moving automobile is entirely feasible. However, because of the many variables involved, evaluation of the data to correlate the aerial, automotive, and ground monitoring survey methods has not yet been completed.

Factors such as the speed of the vehicle or aircraft, the height aboveground, the time lag of the instrument, the attenuation through the vehicle or plane, the larger area from which the instrument detects radiation as the altitude increases, and the topography of the area must all be considered. During the aerial surveys the aircraft maintained a constant air speed. However, in the first shot the wind had a velocity of about 25 knots from the south, which resulted in a large ground speed difference in the north and south direction. The wind was calm during the second shot and this variable was reduced to a minimum.

It was not permitted to conduct surveys in radiation fields over 10 r/hr ground intensities. Therefore, it was necessary to use the T1B ionization chamber instrument for most of the measurements. The range of the CD V–710 was generally too high for accurate reading.

Indoctrination and Training of Radiological Defense Personnel (Project 38.2)

The objective of Project 38.2 was to provide field training under actual nuclear explosion conditions for Federal, State, and local civil defense personnel engaged in radiological defense planning and operations. It was

Figure 20.—Going in—Project personnel make final adjustments to "radsafe" clothing before entering the contaminated area at the Nevada Test Site. The circular devices carried on their heads by three team members (left) are dust respirators.

required that the participants have radiological defense responsibilities and, for maximum benefit, have a knowledge and training in radiological health, safety, or defense.

The first training project was conducted in the 1953 spring series and was attended by 14 persons. For Operation Cue, 14 States, 3 counties and 5 cities sent representatives, with a total participation of 24 persons.

Emphasis was placed on field participation, with classroom lectures held to the minimum required for the trainee to become acquainted with programs of the Civil Effects Test Group and Military Effects Test Group. Group discussions on the application of these programs to defense planning and operations were encouraged. The trainees took part in the technical projects of Programs 31, 38, and 39, in the CD Field Exercise, and in on-site monitoring exercises.

Offsite Radiological Defense Training Exercise (Project 38.5)

The purpose of Project 38.5 was to provide realistic training of personnel responsible for State and local radiological defense planning and operations, and test equipment by conducting field exercises in the fallout area from an actual nuclear detonation. Exercises of this type, conducted under actual fallout conditions, are most valuable for training and planning purposes as

they closely approach the conditions that will be encountered following an enemy attack by nuclear weapons.

The project operated off-site and utilized unclassified information only. Participants, numbering 49, were those who have regional and local civil defense responsibilities in the State of California and who had received sufficient specific training in radiological defense. All expenses were borne by the agency sponsor or by the individual.

The trainees were divided according to duties into a control center group, a monitor group, and a laboratory group. Four mobile laboratories were used, each staffed by 3 specialists. Communications were maintained through 30-watt portable transceivers and "handie-talkies." Necessary equipment and radiological instruments were supplied by the California OCD.

As this was an operational-type project, no specific data were sought or obtained. The results of the training exercise were as follows:

(*a*) The trainees and the staff of the State OCD received valuable experience in conducting a large-scale monitoring operation.

(*b*) The equipment and instrumentation of the State Radiological Safety Services successfully passed a thorough field test.

(*c*) The operational plans of the Radiological Services were thoroughly examined and generally proved to be sound. In the light of the experience gained, the operational plans can now be evaluated.

(*d*) The need of thorough training at all levels of a Radiological Defense Service was demonstrated.

THE CIVIL DEFENSE EXERCISE

The civil defense field exercise held in conjunction with Operation Cue was the first of its kind ever attempted, and was planned as a limited prototype operation from which to gain experience in the conduct of such exercises.

At maximum strength, before the series of shot postponements took their toll, the field group consisted of 400 volunteers drawn from civil defense forces throughout the country, plus Civil Air Patrol personnel. Quotas were assigned on the basis of the number of persons which could be accommodated at the Nevada test site. The exercise was commanded by Brig. Gen. Clyde E. Dougherty, civil defense director of Detroit, Mich., with Jack Lowe, civil defense director of Portland, Oregon, as operations officer, and Maj. Gen. Ralph Olson, civil defense director of Wisconsin, as chief of staff.

The exercise included the services of mass feeding, sanitation, health, warden, police, fire, engineering, rescue, and communications in addition to an administrative exercise staff.

Figure 21.—Real Desert "Rats"—The Field Exercise Participants, headed by this assembled command staff, lived and worked under "down to earth" conditions at Camp Mercury. FEX Coordinator was Maj. Gen. C. E. Dougherty, Detroit, Mich., (seated center, at wheel of vehicle).

The exercise, which began with the initial staff meeting at Camp Mercury on April 17 and concluded on May 6, provided valuable information for any future training activities.

Résumés of individual service operations are as follows:

Sanitation Service

Sanitation services were provided at 2 locations, Media Hill and in the firing area. The principal function of the sanitation service was to demonstrate the control of those public health hazards which generally are associated with large groups where there is close contact between individuals, and where there are mass feedings.

This service was composed of 7 members drawn from State and municipal health agencies, headed by an FCDA sanitary engineer. The group provided food sanitation and food-handling inspection services for the mass feeding operations, including provision of portable handwashing facilities for food handlers, and a safe water supply. It also provided facilities for the safe disposal of human waste, garbage, and refuse.

The facilities at Media Hill made some concessions to comfort, while those made available in the forward area were even more primitive than facilities most likely to be in use under actual disaster conditions.

The Clark County Health Department, in Las Vegas, Nev., contributed materially to the success of this operation by supplying water testing equipment, food inspection thermometers, and information on the sanitary conditions of the various local sources of food distributed in the mass feedings.

Engineering

The safety or engineering group was composed of 1 engineer from each of the 7 FCDA Regions, 12 engineers from States and muncipalities, with the FCDA Safety Officer acting as director.

One responsibility of civil defense engineers is to inspect buildings, dwellings, and utilities damaged by blast. This group made pre and postshot inspections of all test structures, equipment, and utilities from the 4,700-foot to the 15,000-foot lines. During postshot inspection, those structures considered to be unsafe for occupancy were posted "off limits" for observers and others who were to visit the site later.

The engineers also determined which structures could be used with only slight repairs, such as sealing windows and doors, and those buildings which were potentially useful but which needed more extensive repairs such as bracing.

The field exercise provided an opportunity for participating engineers to work closely with technicians of the test staff to obtain valuable background data and information on weapons effects.

While at Camp Mercury group members formed a society, Operation Cue Engineers, and elected a president and secretary. A constitution is being drafted with the objectives of stimulating interest in civil defense among the engineering profession and disseminating information regarding weapons effects and FCDA-recommended procedures in pre and postattack planning and operations.

Health and Casualty Care

The broad areas of coverage by this service included a camp physician for the field exercise and FCDA Headquarters at Camp Mercury, first aid and ambulance service for the observer group and field exercise participants in the forward area, administration of the casualty care portion of the field exercise, and supervision of the sanitation portion of the field exercise.

Approximately 35 of the original group of 80 witnessed the nuclear detonation. On the day following the explosion a collecting station was established in the garage of a test building at the 4,700-foot line, and a simulated first aid station was set up in a utility building at the 15,000-foot line.

Casualty care personnel received simulated casualties from the rescue service, transported these by stretcher to the collecting station, and by ambulance to the first aid station. These operations were coordinated by means of a field telephone system.

Police Service

The mission of the police service was to provide traffic direction, and to assist the test organization in enforcing security and safety measures within the Nevada Test Site.

The group consisted of 42 persons representing top echelons of the police service from all sections of the country. It was organized into 7 teams of 6 persons each, 1 of which was designated team leader. The FCDA director of police service supervised all activities, operating from a command car provided by California civil defense authorities, and equipped with 2-way radio communication between both the field exercise control center and each team leader. Team leaders and their assistants communicated from jeeps, while other members were on foot and in voice communication with their team leader.

Specific duties included direction of buses to unloading and parking areas, direction and control of observer and field exercise movements, enforcement of safety and security measures, preventing interference with test items before and after the explosion, direction of individuals to proper positions on shot day, and prevention of unauthorized handling or carrying away of materials or souvenirs after the explosion.

Owing to the series of postponements, the service was spread thinly at actual shot time, and it was necessary to obtain assistance from the warden service. However, the warden service reported participants had an excellent opportunity to observe and take part in problems to be expected in an attack, and valuable experience was obtained in using improvised emergency communication, transportation, feeding, and housing facilities.

Warden Service

The warden group consisted of 35 individuals from the higher echelons of warden services throughout the country. It was organized into 5 teams of 7 persons each with team captains. About ⅓ of these persons were women.

The final mission was a reconnaissance by warden teams, reporting and marking structures after the test shot; assistance to police service in mobile traffic direction and control, guard details and enforcement of safety measures; and assistance to welfare forces in mass feeding.

The teams operated on foot with the FCDA warden service director supervising from a jeep, which was equipped with a 2-way radio for communication with team captains.

The wardens joined forces with the police service after the series of postponements reduced their numbers to about 2 teams.

Nevertheless, those who did remain expressed the opinion that the explosion was well worth waiting for, and that experience and knowledge gained would be invaluable in stimulating and administering local programs. Nearly all wardens took ample photographs of the operation, some in 35-mm color, to use as lecture material.

Rescue Service

The rescue service was composed of three 7-man teams headed by a leader and assistant leader, and was under the supervision of the FCDA rescue chief. All participants were graduates of the 2 weeks rescue instructor course at Olney, Md., and were selected from active rescue organizations. Three vehicles carrying standard rescue equipment were provided by California, Oregon, and Washington, and a fourth from FCDA Region 7.

Personnel reported on shot day minus 4. On the following day they were oriented and taken on a tour of the forward area. Teams checked their communications, truck and equipment, and held refresher courses in rescue techniques. Later they attended a briefing session on communications procedures.

Two days before the scheduled detonation members attended lectures on the development of civil defense service teams, blast and radiological effects, thermal effects, and medical considerations. They returned then to refresher courses and went through practice runs. The day before the blast the rescue members received final instructions and carried out practice runs.

Approximately ⅓ of the members were lost to the exercise owing to postponements of the shot. Two teams were formed in a reorganization, and these took part on the shot day tour.

The day following the detonation rescue teams moved into the forward area and occupied prepared positions. All mannequins, simulating casualties, were removed from a wood-framed residence in less than an hour; but removals from a brick residence required 1 hour and 40 minutes. The mannequins were turned over to litter bearers of the casualty service after being properly tagged.

Figure 22.—Rescuers at Work—Rescue teams of the Field Exercise Program moved into the "disaster" area on Shot Day plus One to recover simulated injured in the form of mannequins. Several mannequins were buried deeply in debris, and extrication was difficult.

Fire Service

Thirty-five representatives of the Nation's civil defense fire services participated in Operation Cue under the supervision of the FCDA specialist in fire defense training. (Operational headquarters were established at the Camp Mercury fire station.)

The first service had a dual function of augmenting fire protection at crowded Camp Mercury and carrying out prescribed duties in the field exercise. Three Class A 1,000-gallon pumpers, purchased through matching funds by the State of California and driven over the Rockies to the Test Site, became the base units of organization. In addition, the Willys Motor Company supplied 3 pieces of fire apparatus, 1 of which was subjected to the test shot for "post mortem" to determine the effects of blast and thermal radiation on its equipment and operation.

In addition to coordinating plans for local protection with the Mercury fire group, the service attended briefings on wartime fire defense and thermal effects of atomic weapons, made field trips to study construction factors and fire conditions in the Operation Cue firing area, and inspected sites of previous tests.

One Mercury assignment was training for decontamination of the camp in the event of fallout. The fire service was included in the preparation and movement of apparatus in mobile support columns to the firing area, along with other emergency units.

Following the shot, the service inspected 3 pieces of fire apparatus exposed to the nuclear detonation as test items in the emergency vehicle test project.

Communications Service

A communications team was provided by the State of California, with 16 communicators from State and county civil defense. Two mobile communications centers (buses) complete with 2-way radio, public address system, and emergency power, and 8 passenger vehicles equipped with 2-way mobile radio, were placed in operation. The police, warden, fire, rescue, and casualty services were each provided with one of the vehicles and a number of 2-way pack sets. The feeding and sanitation services combined, and engineering services were provided with 1 vehicle each.

A field telephone circuit was established between the communications bus near the observer area. Extensions to the AEC telephone system were provided in the observer area bus, the area of the field exercise participants, and forward trench. A public address system was provided to extend the AEC countdown signals from the observer area to the area of field exercise participants, and forward trench.

These facilities provided the necessary communications for controlling the field exercise personnel before the open shot. It was planned that the radio facilities would be moved in for the field exercise after the shot, but

because of the delay in firing, all of the vehicles and most of the California personnel returned to California before the shot. To replace these facilities the Orange County civil defense, from a distance of 350 miles, brought in a radio equipped vehicle with several radio pack sets the following day. Using this equipment, emergency communications were established from the field exercise headquarters to the various participating civil defense services. Communications for the exercise were directed by Warning and Communications personnel, FCDA. The California group was in charge of Willard Whitfield, California OCD.

Comments

1. Recruiting all personnel and equipment from 1 State had a distinct advantage from an operational standpoint, since such a group has worked together as a team and was thoroughly familiar with the equipment and specific operational procedures. However, placing full dependence on only 1 organization has the disadvantage that the loss of this organization removes all communication facilities. When this occurred, replacement mobile equipment of more limited capability was brought in and provided communications for operation at the site of the exercise.

2. Portable transmitter receivers, complete with built-in loudspeakers, have a distinct advantage for most operational purposes over the type of equipment provided only with telephone handsets.

3. Equipment used in the exercise was brought in from California by bus and sedan cars for distances of from 300 to 500 miles. Several of the items required adjustment upon arrival at the Test Site. It cannot be overemphasized that, for civil defense purposes, all of the mobile equipment must be rugged in construction.

4. The need for carrying maintenance and repair facilities was well illustrated. One of the main transmitters in the mobile control center was not functioning properly, and a number of the receivers required adjustment. All repairs were conducted on the site with the equipment carried.

5. The emphasis which FCDA has placed on emergency power supplies was substantiated. The motor generator sets and associated floodlights were invaluable in operating equipment where no AC power was available.

6. Organized saboteurs can easily destroy communications facilities not guarded 24 hours a day.

7. In the operation of mobile control centers: (a) between fixed points all messages normally should be of the written type; (b) each center should have a controller responsible for all incoming and outgoing messages; (c) there is a strong and continuing requirement for adequate messenger service; (d) unauthorized persons must be kept out of the center, which should be either locked or guarded during operations; and (e) every center should be equipped with an efficient public-address system.

MASS FEEDING PROGRAM

BY JOHN J. HURLEY, *Chief, Defense Welfare Services, Bureau of Public Assistance, Department of Health, Education, and Welfare*

Objectives

The objective of this program was to contribute to the physical comfort and well-being of the official observers, media representatives, and field-force participants by providing hot coffee during the early morning hours before the shot, a tasty breakfast immediately thereafter, and a nourishing lunch on the day following. In providing this service the mass-feeding exercise demonstrated the following:

Effective methods and techniques for preparing and serving food under difficult conditions.

The ability of professional feeders of diverse organizations to work effectively as a team in unusual surroundings with unfamiliar equipment.

Importance and adaptability of a unique national fuel resource in emergency feeding.

The extent to which improvisation can be utilized in emergency feeding, planning, and operating.

Mobile feeding units need not be elaborate and can be assembled from equipment already available in any community.

Safe and sanitary methods for storage, transport, preparation, and serving of food.

Type of support activities which other civil defense services can render in mass-feeding operations.

The high level of interest and willingness of the feeding industry to participate actively in civil defense.

The willingness of allied industries to cooperate in underwriting this project.

How It Came About

The idea of this feeding demonstration started with Operation Doorstep of the 1953 AEC test series. All food served to the official observers at this test was provided by a commercial caterer and paid for by each individual. The limited bill of fare brought the recommendation of the FCDA welfare office that, at the next open shot, opportunity be afforded to demonstrate emergency feeding techniques with food provided at no cost to the Government or to the individual observers. This proposal was further explored with the newly created National Advisory Committee on Emergency Feed-

ing. It approved the proposal and recommended that the committee be utilized in planning such a program.

In June 1954, a subcommittee was formed to outline an overall plan for the exercise; each member of this group was assigned a specific responsibility for determining the feasibility of procuring the food, fuel, and equipment through contacts with the feeding and allied industries. The plans developed were reviewed and amended by the full committee in meetings held in October and December.

Problems Encountered

In planning this program the committee was fully aware of the problems of distance from sources of supply, the extreme climatic changes in the desert, and the limited communications facilities available. Every phase of the feeding program was planned with these limitations in mind. The feeding team had to be: (1) self-sufficient, with its own transport, food, fuel, lighting, and supplies; (2) mobile, capable of setting up feeding operations anywhere in the test area, and (3) flexible, adapting its operation to changes in the overall program of the exercise.

As a result of the series of postponements, rolls and doughnuts had to be purchased several times. Other supply items, such as paper cups, spoons, coffee, and certain staples had to be replenished. Even the eggs which had been kept under refrigeration had to be replaced. Transportation of these items to Camp Mercury had to be provided by the feeding team. The demonstration included the movement of hot coffee by air from Chicago and baked beans by overland freight and CAP aircraft from Los Angeles. Each postponement and each rescheduling of the shot necessitated communications with both Chicago and Los Angeles. Except for the stepped-up cooperation of the organizations participating, this phase of the demonstration would have had to be cancelled.

Other problems, minor by comparison, were encountered even before the start of the exercise. Radical adjustments had to be made in the equipment and transport requirements due to the unavailability of certain types of equipment and supplies in Las Vegas and the limited storage facilities at Mercury. Considerable time of the subcommittee was spent, at the last moment, in securing folding wooden tables, cooking utensils—such as stock pots, large roasting pans, and serving equipment; it was not expected that these would be in short supply in Las Vegas. The wooden tables were eventually obtained and transported in from Los Angeles.

Team Composition and Organization

The overall quota allotted to mass feeding in the field exercise program was 61. An individual quota was set for each of the participating organ-

izations by the committee. Each organization selected its own participants and alternates. Some 110 persons were cleared for the exercise. Twelve of the 61 regular selectees were unable to accept and were replaced by their alternates from the same organizations. Fifty-nine participants arrived in Mercury on shot day minus 4. This group represented the top personnel in their respective fields and came from all sections of the country. There were hotel operators, restauranteurs, chefs, stewards and caterers, industrial feeders, dietitians, home economists, school food service supervisors, Red Cross canteen and public welfare personnel, technicians from the LP gas, paper cup, and allied industries. Many of these were presidents or chief executives of their companies and organizations; 10 or more were current or past presidents of their professional associations.

The 6 food service teams were organized to include a chef, 2 assistant chefs, 3 servers, and 1 fuel technician on each team. The coffee team consisted of 10 persons. Each team chose its own leaders who would be responsible for the work of the team.

Menu

One of the early decisions reached by the committee was that the following menus would be served:

Field Breakfast

Orange and grapefruit juice
Scrambled eggs, scrapple, bacon
Rolls, butter, marmalade
Coffee and milk

Field Luncheon

Tomato juice
Irish beef stew, roast beef sandwich
Baked beans, rolls and butter
Ice cream, candy, apple
Coffee and milk

The choice of menus is perhaps best expressed in the souvenir program:

"The menus chosen for this demonstration have not been selected to give any preview of 'hardship' conditions. On the contrary, the committee hopes the meals will be pleasant and tasty—however, as in an emergency the importance of simple, nourishing, energy-giving foods is accented.

"Civil defense feeding forces must be prepared to furnish meals with whatever food is available. Food will come, as in this exercise, from all of the following sources: local retail stores, local wholesalers and manufacturers, and from cities outside the area."

In the committee discussions objections were raised to the preparation of meat dishes from the raw state in view of the anticipated heat and primitive operating conditions.

Improvisation

Originally the committee was not unanimous as to the inclusion of improvised methods of cookery in the demonstration. It was the majority view that the entire operation was itself one of improvisation and that further innovations would be unnecessarily complicating. The group finally approved providing for the roasting of beef in shortening cans over an open fire. No attempt would be made to construct brick ovens although grills might be set up using rubble from the test houses. The committee felt that overemphasis on this phase might cause a false impression that emergency feeding as conceived under modern attack assumptions could be accomplished with such methods only.

Fuel

It was natural for the committee to choose liquefied petroleum gas as the fuel to be used in the demonstration. It was easily transportable in cylinders of from 20 to 100 pounds and was safe in the hands of competent technical personnel. It could also be used to operate kitchen stoves from the damaged test houses and thereby demonstrate its unique contribution in emergency feeding—surviving kitchens can be made operable even though normal gas utilities may have been disrupted.

Equipment

The committee ruled out the use of ovens as too elaborate and not of a type easily moved on and off the trucks. The feeding plan called for the use of improvised, mobile feeding trucks capable of storing and transporting all of the equipment and supplies necessary for preparing and serving food in the test area. Three trucks would be equipped for food service and the other for coffee service; all carried three 100-pound tanks of LP gas. Equipment would be so arranged on the food trucks that a feeding stations could be set up on each side—6 stations in all.

Each food truck would carry six 4-burner gas stoves, 4 countertype griddles, ten 8-foot folding tables and sufficient food supplies, paper service, cooking and serving utensils to feed 600 to 800 people. The coffee truck would carry 8 folding tables, ten 40-gallon stock pots, ten 10-gallon thermo-liquid urns, 4 "coffee walkies," 8 round utility gas stoves, and sufficient supplies of coffee, powdered cream, sugar, paper cups, napkins, and spoons

to serve several thousand persons. There were 2 additional pieces of mobile equipment—a refrigerated truck and a covered truck which carried nonperishable food supplies, thermal urns, and other items.

Food Service

There was considerable discussion in the committe session as to how food would be served in the exercise. It was decided that paper service would be used throughout. Not only would its use speed the serving of the food but it would also reduce the possibilities of food contamination. Because of the variety of food in the planned menu some 10 different types and sizes of paper food containers would need to be utilized. Methods of dispensing food would require a minimum of handling by those manning the serving lines.

What Was Done

The feeding team prepared coffee and snacks on 7 occasions during the exercise. A conservative estimate of the coffee served was 55,000 cups. Coffee, sweet rolls, and doughnuts were served throughout not only to official observers and media representatives in the observer area but also to more than 300 civil defense field personnel at Position Able and the small volunteer group at Position Baker. Breakfast was prepared twice, not including "dry run" day when it and parts of the lunch were served to 150 field force participants. The luncheon was served only once; there were approximately 1,200 servings of breakfast on the morning of the shot and 1,100 servings of the luncheon on the day following.

The feeding program outlined in the souvenir menu was followed to the letter. As planned, coffee and baked beans were brought in from distant points and served piping hot without reheating. One addition to the luncheon menu, since it was Friday, was fish.

One of the major points to be demonstrated in the breakfast was the rapidity of food preparation. On the morning of the initial postponement preparation required 30 minutes and on the morning of the actual shot 25 minutes. This represents the time elapsed from the undoing of the first knot on the tarpaulin covering the food trucks to the time when all of the 4 food stations were able to begin continuous serving of breakfast; some stations were ready to begin a few minutes earlier. It should be pointed out that before food preparation could begin, stoves and equipment had to be removed from the trucks, placed on tables and connections made to the gas cylinders which remained on the trucks. The serving of both the lunch and the breakfast was completed in less than 50 minutes, including the serving of seconds, thirds, and even fourths to a few.

How It Was Done

Before arrival in Las Vegas each member of the feeding team had received a detailed outline of the proposed feeding program, its objectives, and a diagrammatic chart, drawn to scale, of the feeding arrangements. Because of other events scheduled briefings were most limited. The committee also planned a "dry run" of the demonstration; its purpose was to offer an opportunity for the team to get better acquainted, familiarize themselves with the equipment and the surroundings in which the feeding would take place, and generally to test the feeding arrangements. As it turned out this "dry run" was a real test of both the team and its equipment. In winds of 50 to 60 miles per hour the breakfast and part of the lunch menu was prepared and served to some 150 field force participants. The feeding team did the entire job—even dug its own post holes and set up a substantial canvas windbreak which stood up under the heavy wind conditions.

Much was learned from this experience. While the original program was not changed, some of the methods for carrying it out were revised. For example, it was decided that the eggs would be shelled in Camp Mercury and kept in tightly-sealed stock pots which would be maintained under refrigeration at all times. Frying of bacon on the grills proved to be a slow process under the wind and altitude conditions. It was decided therefore to precook the bacon, maintain it under refrigeration and mix it with the eggs just prior to cooking. These changes contributed materially to increase the speed of the breakfast preparation.

All of the equipment except the stoves functioned effectively in this test. Of the 3 types of heat transfer units, only the gas utility stoves were efficient in the severe winds. While it was unlikely that such winds would be present during an actual shot, the fuel representative on the committee had 14 similar stoves air expressed from the East Coast the same day.

As expected, the coffee service was a volume operation which could be easily adapted to meet program changes. Since security regulations did not permit movement between areas, coffee for the Baker and Able positions was prepared before the team departed from Mercury each evening and placed on the convoys assigned to these locations. It was also simple to set up special urns to service the "coffee walkies" when it was found that this service was congesting the serving area of the coffee station. Coffee was prepared and served under all possible weather conditions.

Problems within the team's control were easily managed. An excellent job was done even when it presented problems outside control. For example, on one occasion, the feeding team was the last unit to arrive in the observer area. It was scheduled to arrive 1 hour and 15 minutes before the official observer convoy. It was an extremely cold morning and quite un-

derstandable that after an hour in the open something warm was in great demand. To call it a "run" on the coffee station would be putting it mildly. However, within 15 minutes after the team's arrival, coffee and doughnuts were being served and not long thereafter the 6 serving lines had dwindled practically to stragglers.

These were difficult and somewhat frustrating situations which the feeding team encountered. More vexing was the inaccurate interpretation and reporting of these events by isolated individuals. As was to be expected, there was a complete lack of knowledge on the part of the uninitiated of what it takes to do the kind of job which this feeding team had set as its objective. This was not a mere show of equipment and methods but a concrete demonstration of how food can be actually prepared and served under adverse conditions. Food poisoning can occur under the most favorable of conditions. Many well-earned reputations in the food field were "on the line" in this exercise—a variety of food, some susceptible to rapid contamination, would be prepared and served under difficult and primitive conditions. The postponement of the shot only served to intensify this problem. The feeding team was constantly on the alert due to the fact that it had a tangible end product—the providing of food.

The weather briefings were of special significance. A favorable report from the morning briefing meant that food had to be ordered from Las Vegas and the participating groups in Chicago and Los Angeles alerted. An unfavorable report necessitated similar contacts. A favorable report from the evening briefing necessitated the taking of additional steps—moving the refrigerated truck from Las Vegas, preparation of coffee and delivery of coffee and snacks to the Baker and Able convoys. After each postponement the equipment had to be cleaned on return to Mercury and the trucks reassembled and reloaded, to be ready to move the same evening if necessary. With each outing the feeding team functioned more smoothly even though its numbers gradually shrank to slightly less than half.

The major objective of the luncheon was to demonstrate not only speed of food preparation but improvisation. Three types of improvised cookery were shown.

Twenty-pound sirloin butts of beef were roasted in 110-pound shortening or lard cans over a charcoal fire set in a shallow trench. The beef was suspended by wire. After 2½ hours the lids were removed, the beef sliced and served on a bun dipped in the juice of the meat. Frozen fish double-wrapped in aluminum foil was prepared on grills built from the rubble from the damaged structures. Some of the foil had been previously used the morning before to protect the upholstery of the jeeps, which were in the Baker area at the time of the shot, from thermal radiation.

A gas stove removed from a kitchen of one of the damaged houses was set up in the feeding area. This stove was in operation in less than 10 minutes after having been converted to the use of LP gas.

Because of the depleted staff and the smaller number to be served only 2 feeding stations, operating from a single food truck, were established for the luncheon. Improvised cookery was done in front of this truck and between the 2 stations; coffee service was in the rear as was the refrigerated truck in which was stored the perishable foods, including milk and ice cream. In effect it was a single station with 2 serving lines. The Irish beef stew was ready early in the morning and served to the media representatives who had to return to file their stories. It was prepared from canned meat, potatoes, and onions with each of the chefs adding his own particular brand of seasoning. The baked beans arrived on schedule in Las Vegas. Part of the shipment was brought in by air and part by private car from that point to the Test Site. This luncheon was served a half hour earlier than planned—as soon as the roasting of the beef had been completed.

Figure 23.—Feeding en Masse—The mass feeding demonstrations on Media Hill and in the forward area (see damaged residences at the 4,700-foot line in background) brought practically 100 percent participation as this "chow line" testifies.

POSITION BAKER

(A volunteer field exercise mass feeding participant and hotel executive presents an account of his experiences in Operation Cue and particularly as a member of the Position Baker team.)

ARTHUR F. LANDSTREET, *President and General Manager, Hotel King Cotton, Memphis, Tenn., and Member of American Hotel Association*

I arrived at Las Vegas about noon April 22, went to the high school, checked in, and bought a round trip bus ticket to Mercury, Nevada.

On Saturday, or shot day minus 3, we went to observe all of the forward areas. This was interesting, and together with much briefing we began to get an idea about the whole situation.

Among other things, we were told that out of our group, one person was to be chosen to go into Position Baker. This was a trench at the 3,500 yard line, which was forward of any spot that civilians had been allowed to observe an atomic blast. The group at Position Baker was made up of 29 persons, selected from the several field exercise groups.

On Sunday, shot day minus 2, we spent most of the day in briefings. We were told that on a high pole in the center of the camp were 2 lights, 1 red and 1 blue. The flashing red light indicated that there would be no shot until the next briefing time. The flashing light indicated that the shot was "on" unless a later briefing reported that conditions were unfavorable.

Later in the afternoon volunteers were called for to go to Position Baker. I volunteered. It was necessary for me to take a medical examination which I passed with a perfect score. On Monday, shot day minus 1, the mass feeding group, after being briefed, proceeded to the forward area to rehearse the procedures that would be followed after the burst of the bomb.

Following a hypothetical detonation we unloaded trucks, set up tables, put all equipment into position, and cooked enough food to feed our own group of about 60 persons. This job was done under most trying conditions. A sand storm with winds up to 75 miles an hour appeared to approach us from all sides. At times the sand was so thick in the air that we could not see our coworkers 20 feet away. It was necessary to protect the stoves by erecting a canvas fence around the area. This was done with great effort, at times the wind would practically take us all away. Everybody jumped in, digging holes, erecting tent poles and tying them down to iron stakes. Finally we had a canvas fence around the operation.

We found once this was done, we had erected the fence a bit too far from the stoves and wagons, and the suction behind the fence was practically as bad as the wind itself. It was too late to correct this, but now we knew what to do if similar conditions existed following shot time.

It was a very trying day and we were all quite weary by the time we returned to Mercury about 4 p. m. I was immediately informed that members of the Baker Operation team were to be briefed at 8 p. m. that night in one of the administrative offices. We rushed for shower baths, got a few hours rest, had dinner, and went over to the briefing on Baker.

For an hour and a half we listened to the story of what was expected of us in this forward position. Apparently the reasons for stationing civilians at Position Baker was to find out what the actual reactions from citizens who were not schooled in the atomic field would be, and to get some idea of what the ordinary citizen might be able to endure under similar conditions. This idea was a part of the total pattern to condition civilians for what they might be expected to experience in case of atomic attack.

It was 9: 30 p. m. when we finished briefing, and we were curtly and bluntly told to return to our barracks, get on warm clothing, get a cup of coffee and return at 10 p. m. to go to Position Baker.

The wind was blowing 50 to 80 miles an hour, and the temperature was about 25 to 28 degrees. Brother, it was rugged! At 10 p. m. we were put into open jeeps to travel 30 miles to Position Baker. Leaving the main highway we reached Position Baker approximately 2 miles away. We made that last 2 miles again and again, 8 or 10 times. For some three hours we were drilled in everything that we might be expected to do. Finally the drivers, jeeps, and passengers made what seemed to be a satisfactory run from the highway into the trench, and we all sighed with great relief, thinking that we had finished. Then the director advised that the run was satisfactory, but we would make it again in order to groove the situation.

So away we went back to the highway, and with a great flourish and much dramatization we returned to Position Baker, jumped out of the jeeps, and proceeded into the trench itself. There we were drilled time after time, how to stand, kneel, dress, and put the helmet on the back of our head to protect that fragile connection of mind and body from the devastating blast of the explosion itself. We were told to have something heavy around our neck such as a bath towel and to pull the helmet back on our neck so that it would be completely protected.

Every step of the bomb burst was explained over and over from the moment of the first flash of light until the devastating blast. We were asked to make time tests from the trench to our jeeps. We did this time after time, endeavoring to create more speed and less loss of motion. We

were told that this was necessary because, if the bomb exploded directly over us with practically no wind, the fallout would drop immediately downward, and we would be alerted to get out of the territory. We would have about 5 minutes to get at least 2½ to 3 miles distant, so it was necessary that we learn every move perfectly.

In one of the final tests from a standing start in the trenches we were all loaded in the jeeps, and the jeeps in motion in 2¾ minutes; this meant that we could get away in ample time before the fallout began to arrive on the earth. If the bomb had exploded on Thursday morning, April 28, we would have had to make this evacuation. We had already been warned that the moment we could get moving after the blast we should rush to the jeeps and get out of the territory with all speed.

At 2 a. m. we were advised to load the jeeps for return to Camp Mercury. I think everybody would have shouted if they had energy enough, or could have thawed out their vocal cords to the point that a noise could be made. We were really cold. That ride home will be forever remembered as one of the roughest moments in my life.

The driver of the jeep I was in was Stephen H. Taylor from Boise, Idaho, and a member of the fire department. He was as totally unprepared for the severe weather as I was. We both lamented, and almost cried over the fact that we had parkas and other warm equipment hanging in the closet at home, and there we were with every need for further protection. I did bring a blanket along and managed to drape the blanket around Taylor and myself. I turned my gloves over to him as he did not have any. Crouched together in common misery, we made that 30 miles.

We arrived at Mercury at 3 a. m., and the commander of the group called us together and told us to be back on duty at 8 a. m. We were again returning to Position Baker for further drills. Oh boy, and did we groan! Thus ended a record day from very early morning until earlier the next morning.

According to the scheduled plan, the bomb should have been detonated about 2 hours after the time we returned from that grueling night, but during Monday, the briefing office canceled the shot for Tuesday and set it up for Wednesday. On Tuesday morning at 8 o'clock we entered the jeeps, returned to Position Baker, and with the wind still blowing and the temperature very cold, we repeated all of the drills of the night before. In daylight we were able to see the terrain and understand the location of our position in relation to the detonation point.

When we returned about 3 p. m., our hopes and general attitude were stimulated to find that the blue light was burning and the shot was on for the following morning, Wednesday, April 27. We rushed to our huts, took shower baths, got into bed, and in spite of the excitement and anticipation of a shot the next morning I was not long awake. I slept well from about

5 p. m. until 10 p. m. when I was awakened by my cabin associates, among them Vernon Herndon and Arthur Packard, and we prepared to move forward for the shot area.

By midnight the buses were loading, but again we occupied the open jeeps. While the weather was not as windy, it was considerably colder and it was a rugged drive. At News Hill we picked up Dave Garroway and his crew of television workers. For about 2 hours and a half we waited, had a couple of drills, and watched with interest Garroway's crew set up his show. Everybody was in good spirits.

At shot time minus 1 hour we heard a dull and drab voice announce the shot was canceled because weather conditions were not satisfactory. We all just stood and said nothing. Orders were given to man the jeeps, and we returned home about daylight.

When I think of all the experiences at Mercury probably the most pleasant were the hot shower baths, and the warmth of the room in which these baths were located. I think I must have spent ½ hour under that shower. I went to bed, and I had a full day's sleep, getting up around 4 or 5 o'clock in the afternoon to find that the shot was on for the following morning, Thursday.

Again our spirits rose. We went to the dining room for food, came back and rested for a while. There was a note that all members report at 10 p. m. at headquarters for further briefing.

After some delays Harold Goodwin, director of our activities, gave us further information and data about the bomb shot for that particular morning. In much detail he advised us that in all likelihood we might have to evacuate the trenches quickly, and to be prepared to do so. He reminded us of the drills we had for that purpose. Shortly after midnight, in the open jeeps, we set out for Postion Baker, we stopped at News Hill and picked up the television group, and again all the processes of the previous night were reenacted.

I forgot to mention that the first night at Position Baker I was asked to monitor a walkie-talkie for Director Goodwin. This was interesting because I was able to hear all the conversations passing from one operation to the other. Whenever our position was called from administration headquarters or other operation points I would take the walkie-talkie to Goodwin and let him carry on. Each night that we were in the trench I did this monitoring work.

Actually it was quite a help, it kept me mentally busy, and most of the time I was out of the trench in close proximity to Goodwin so that there would be no delay in the transmission of messages. I was not as cold out on the surface of the ground as I was in the trench. The cold seemed to settle in the trench, and walking about seemed to keep my feet warm.

As time elapsed and shot hour approached our excitement began to increase. At shot time minus 1 hour a large amount of dynamite was exploded in order to make tests of the winds in the upper atmosphere. In due time a report came in over the walkie-talkie that the results were satisfactory and the shot was on.

At shot time less 30 minutes the report came through that conditions were still satisfactory and the shot was on. At approximately shot time minus 15 minutes the drab voice again announced that weather conditions were *not* satisfactory and the shot was called off.

For about 5 minutes after the announcement Position Baker was the coldest place on earth. Everyone was at the lowest possible ebb and we practically crawled out of the trench to go to our jeeps. Nobody talked, everyone was too disappointed.

We returned to Mercury and to the hot showers. We were further disappointed when an announcement came that the next detonation was set for Saturday morning, 2 days away. At least we knew we had time to rest, and we went to bed to sleep all day and part of the night.

On Friday many groups were organized to visit Las Vegas, Boulder Dam, Death Valley, and other points of interest. Catching up with our rest, and a trip into Las Vegas, made the time pass by with remarkably good speed.

Saturday morning found us back again at Position Baker having gone through much of the same type of preparation from Friday evening around 11 p. m. until we arrived at the forward trench. Some guardian angel had looked after us, and on this trip we had a bus that took us out to News Hill. The jeeps were sent ahead. The bus was probably the oldest and most dilapidated that I had ever ridden in; there didn't seem to be much of a muffler on it, and when we hit the hills it sounded like a jet plane taking off. I will say this, it was the most comfortable, most luxurious ride that I can ever remember in comparison with those jeeps. At 1:30 Saturday morning we were in position and again our hopes and excitement were high.

Gen. Dougherty, in a briefing before we left camp, advised us that wind conditions were perfect and the only thing that would cause a delay would be clouds. There were a few clouds floating in the sky, and we watched their development with keen interest and a lot of wishful thinking. As the morning progressed the clouds seemed to get heavier and finally at shot time minus 2 hours the sky was overcast and that drab voice once again told us that weather conditions were not satisfactory and that the shot was called off.

During the late hours of morning there were traces of snow and sleet. When we boarded the jeeps to take us back to News Hill it began to rain hard and continued all the way, so we were wet as well as cold and disgusted by the time we returned to Mercury. From Sunday until Wednesday the

weather did not improve to the point where it could give us much encouragement.

However, the Federal Civil Defense Administration was very thoughtful and arranged trips to Boulder Dam, Death Valley, and even removed restrictions to the extent that we were escorted through contaminated areas to see the results from earlier shots. This was all impressive and made our trip well worthwhile. Wednesday the weather seemed to be clearing, and we began to have the feeling that the shot might be in the offing. Many of our crowd had gone home, and from the 60 in mass feeding, the group had dwindled down to approximately 20 or 25.

During the day the blue light came on to signal the probability that the shot would be made. At the 9:30 p. m. briefing the announcement was made that everything looked good for a shot. Excitement began to rise and Wednesday night we were on the way to the Position Baker trench feeling that something was about to happen. We were in the trench by 2:30 a. m., Thursday, May 5.

Dave Garroway was not present, but Roy Neal was there in his place. I was asked to participate in the television program at shot time minus 7 minutes.

The usual procedures followed: Shot time minus 2 hours there was a weather test that proved satisfactory. Shot time minus 1 hour another test

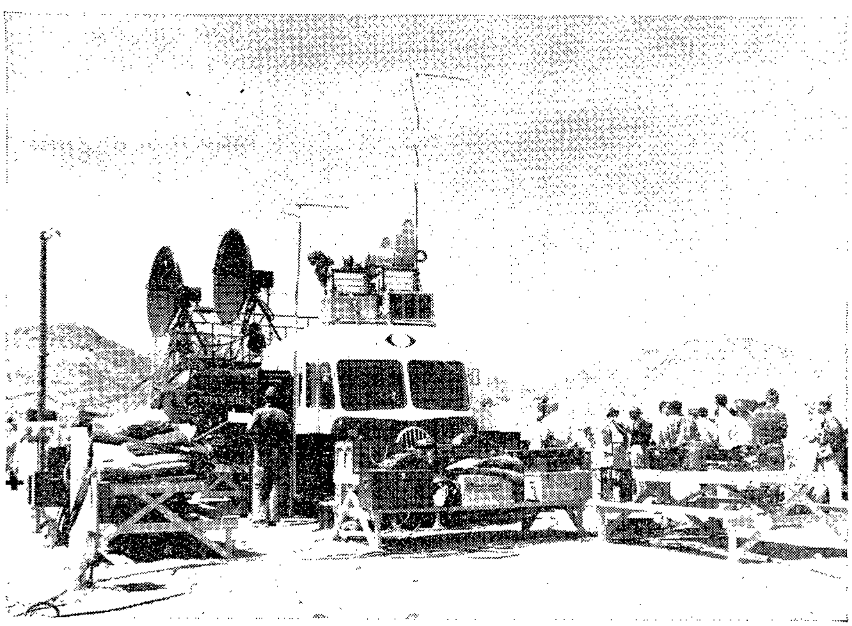

Figure 24.—Test Coverage—Mobile television units on Media Hill were a familiar sight to test observers.

was taken, and on down to shot time minus 30 minutes, when it was announced that everything looked good for the shot.

At shot time minus 7 minutes I was introduced over television as the oldest person in the trench. I was asked how I felt, if I was excited, and so forth. I told them that I felt fine, and was not the least bit worried. The excitement was intense when at shot time minus 5 minutes, the announcement came over the public-address system giving the exact time and that the shot would be made.

Everyone was happy because we knew the long wait was over. At shot time minus 1 minute, the down count started, 45 seconds, 30 seconds, 15 seconds, 10 seconds, 9, 8, 7, 6, 5, 4, 3, 2, 1, ZERO and together with split timing came the terrific flash.

At minus 1 minute we had all kneeled on our right knee and carefully put on our respirators and sand goggles. We adjusted our clothing over the back of our necks with the helmet pulled down deep over the neck to save any blows from falling rocks or shock waves. Our faces were down probably 18 inches from the bottom of the trench, and we were leaning solidly against the trench toward the bomb side. The flash was so terrific that even with closed eyes, it seemed as bright as looking into a flash bulb from a camera only a few feet away.

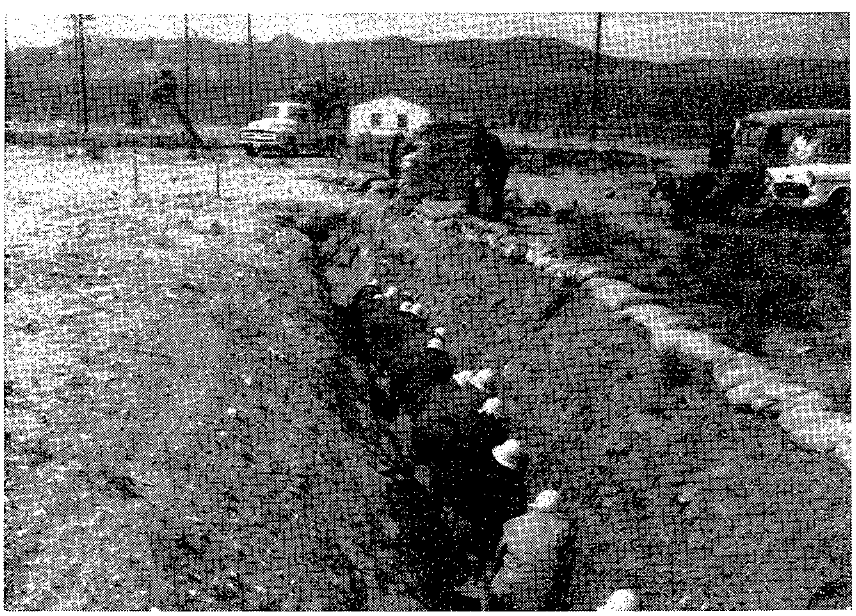

Figure 25.—Position Baker—Twenty-nine adventurous volunteers, including six women, experienced the detonation from trenches only 10,500 feet from ground zero. There were no casualties. Here Position Baker personnel continue innumerable practice runs to insure discipline and approved procedure.

The seismic shock followed immediately. The trench seemed to rock back and forth for several seconds; then the noise and the blast came. If you have ever heard lightning strike within 100 yards then multiply the thunderclap about 10 times, and you get some idea of the terrific blast. If you have heard thunder crash almost on top of you and then roll and roll as if it was continuing way into the distance, then you have some idea of this dramatic moment.

It is difficult for me to describe the feeling of the blast because it was sudden and sharp, I might say that it felt like someone had taken a sand bag weighing about 20 pounds and struck me in the middle of the back. I can understand why they wanted our necks well covered.

In just a few seconds, however, the blast and the noise had passed and we could hear Hal Goodwin through a portable megaphone, calling us to our feet and hurrying us out of the trench. I knew right then that the doctor was correct in saying that my health was good and I was able to take part in the exercise, because when the word came to get out of the trench, I didn't hold up traffic.

By the time I was outside and could look up to the sky there was little to see. It seemed to me that tons of dirt were whirling around and around. Dust was everywhere, nothing but a brown, drab, dead sight was our reward. However, in a very few minutes this began to clear away, and unfolded before us was the mushroom cloud of the atomic blast. This was silhouetted against the sky. There was a slight tinge of daylight in the east and we were able to make out the outline of the entire atomic cloud.

Someone called out that the lights were burning on three of the jeeps. The drivers raced hurriedly over to see if there were any short circuits. There were none, but the jolt of the explosion had turned on the switches.

When the blast came the television lights were blown out, one of the cameras was badly damaged, and the glass in the television truck doors was blown out. How much other damage was done I do not know. Movie cameras had been set automatically, and as long as the lights lasted pictures were made.

Everybody was shouting and howling gleefully that the blast was over. We rushed to our jeeps and hurried to News Hill, where we were introduced to the media and home press observers. I stayed with the crowd a few minutes and then proceeded to the mass feeding area and helped serve the breakfast.

The breakfast went off well, and we received compliments from many of our 2,000 guests. We returned to Mercury, and after a shower and a nap, proceeded to the Las Vegas airport to arrange for reservations.

We were back in camp about 11:30 p. m., and up at 5:30 a. m. We proceeded by bus to the scene of the blast where we served a luncheon

for the media people and observers who were out to inspect the devastation caused by the bomb.

We served a marvelous meal. The roast beef was cooked in lard cans by suspending the beef on wires with fire piled around the can. This was the finest experience in outdoor cooking that I have ever had. The meat was beautifully done, well browned all over. There were many compliments on the excellence of the food.

In closing may I make these observations: Many times I was disgusted, irritated, and resentful over the rough and tough manner in which we were transported back and forth to Position Baker. In all we made nine trips to the area. However, it was my pleasure to talk to our director about the situation after it was over, and as I suspected we, as a group, were being tested to see if we could take it or not. When it was found that we could weather such nights as the first night out in the storm—wind ranging from 50 to 80 miles an hour and the thermometer below freezing—and then could go back the next and the next night, no one complaining, but probably everybody wondering, the men who guide the destiny of these shots felt safe in continuing Baker through to the end. There were times when they felt that possibly it was a mistake to take civilians into the forward area.

Everyone is happy now and those who were privileged to participate in Baker feel that they were among the selected few. I doubt if they would want to go through the experience again, but certainly no one would want to give up the experience. It is the type of thing that you want to do only once.

THE CIVIL AIR PATROL IN OPERATION CUE

BY MAJ. GEN. LUCAS V. BEAU, *USAF, Past National Commander*

With an earth-shattering thunderclap punctuated by the glare of 20 suns, a nuclear explosion equal to 30,000 tons of TNT was detonated at Yucca Flat on May 5, 1955. This shot gave new meaning to the operational role of the Civil Air Patrol—America's civilian air arm and auxiliary of the United States Air Force.

Long dedicated to saving lives, protecting property, relieving suffering through aerial search and rescue, disaster relief in peace, coastal patrol, courier service, and aerial support of civil defense in time of national emergency, the CAP now has a new role.

As the huge clouds of dust began rising to blanket the 20-mile valley and the mushroom cloud threw its ominous shadow over the more than 2,500 observers invited to the shot, the bark of an airplane engine marked the beginning of a history-making flight.

Just 43 minutes after the blast sent its shock wave, deadly radiation, and thermal wave across the desert smashing the homes of survival city, a small, maroon, civilian Stinson took off from Yucca strip 7 miles from ground zero on the first aerial radiation mission ever flown in a civilian plane with a civilian pilot in connection with the detonation of an atomic device.

At the controls of the 4-place private plane was Major Bill Stead, director of operations for the Nevada Wing of the Civil Air Patrol and atomic test project officer for CAP and Operation Cue. His passengers manning a battery of delicate electronic instruments for measuring the strength of radiation were Ben E. Clouser, a civil defense volunteer radiation monitor from Wilmington, Delaware, and Laverne Penn, director of radiological monitoring for the civil defense of Milwaukee, Wisconsin.

For more than an hour the Stinson flew clover-leaf pattern, over premarked spots on the desert floor at different altitudes while the monitors aboard took readings.

Just what level of radioactivity deposited by fallout from the atomic cloud was located and measured by the little plane was made part of a report which will be classified for some time, but the fact that the use of civilian planes with nonprofessional civilian pilots for this radiation measuring work is practical was acknowledged by the monitors themselves.

In addition, Roscoe H. Goeke, Federal Civil Defense Administration program director, said that the light plane was proving to be a reliable aerial platform for the monitoring personnel and their electronic equipment.

This mission and other similar ones flown as part of the atomic test are significant because they point to a new, dramatic way in which the CAP and its light planes can serve the people of the United States.

The missions flown in Operation Cue were part of Civil Effects Test Project 38.1 and were designed to evaluate the use of light planes flown by civilian pilots in this work, and to develop techniques so the Civil Air Patrol and State civil defense agencies can cooperate in the event of an actual atomic attack by plotting fallout areas and transmitting evacuation instructions to the population of those areas.

In actual practice the findings of the airborne monitors would be radioed to the ground where experts would plot them and draw contour maps of the radiation intensities.

There are two major problems which must be dealt with if any American city is struck by an atomic bomb. If attacked, the populace must first face the problem of evacuation; secondly, it must be prepared to bring help to those who are caught within the damaged area. In either case private pilots with their single-engine light-planes based at hundreds of small airports across the Nation will be called upon to perform a variety of missions for which their planes and training are especially adapted.

In the case of evacuation, traffic congestion certainly will throw up roadblocks in the way of the hurrying populace. This is where the small, radio-equipped private plane with its ability to fly low and slowly will be pressed into service providing aerial eyes for police agencies charged with the responsibility of keeping the flow of human traffic moving.

In many cities the planes and volunteer crewmen of the Civil Air Patrol already have begun training for this critical role. City officials and civil defense authorities have been enthusiastic in their praise of the assistance given by light aviation. Foremost among these has been New York City.

Light planes with their ability to operate into and out of small, improvised airfields can be used to great advantage in providing airlift for evacuating children, old people, and invalids from homes and hospitals.

After an enemy nuclear bomb has devastated an American city the light plane and its volunteer pilot have an even more important role—that of bringing in doctors and nurses, blood, medical supplies, and uncontaminated food and water. When surface transportation is hindered by wrecked bridges, toppled buildings, and abandoned vehicles, the light plane can land in vacant lots, athletic fields, stadiums, golf courses, parks, and cleared roadways. Critical supplies and rescue personnel can be brought quickly to the center of the disaster area.

In the 1954 nationwide civil defense test—Operation Alert—CAP planes flying into a 900-foot football field in downtown Washington, D. C., airlifted 1,700 pints of "whole blood" to within 100 yards of the civil defense

command post. In still another training mission CAP pilots airlifted an entire field hospital complete with 16 beds, 2 doctors, 4 nurses, first aid attendants, its own electric power plant, portable operating table, and other equipment into Philadelphia after an "atomic bomb" exploded in the Navy Yard. Contemporary light planes ranging from Cubs to Navions were used.

It now appears, however, that this new role—radiation measuring from the air—may well become one of the most important contributions of our light planes and volunteer crews in time of actual atomic attack.

Even though we do not know all the answers in the field of aerial radiation monitoring many Civil Air Patrol squadrons and groups around the country already have begun intensive training for this work in cooperation with local civil defense agencies.

In Chicago the Illinois Wing of the CAP has begun to install radiation detection equipment in certain of their aircraft assigned to this work. The equipment is being provided by the Chicago civil defense as part of a joint agreement which also calls for civil defense to train CAP personnel in radiological techniques.

A similar program is underway in Milwaukee, Wis., and in the State of Oklahoma. In Oak Ridge, Tenn., Civil Air Patrol authorities in cooperation with officials at the Oak Ridge National Laboratory have gone even farther. Recently ORNL provided a live radioactive target for a CAP radiation detection and monitoring mission. ORNL health physics technicians secreted the radioactive material somewhere in a 12-mile radius of Oak Ridge. CAP planes and pilots were required to find it. ORNL personnel flew with the CAP planes and manned the detection equipment. The target was quickly found. Its perimeter was plotted and marked off by ground crews directed from the air by radio and the radioactive area was isolated.

At the conclusion of the mission Dr. K. Z. Morgan, Director of Health Physics at ORNL, said that the test was a great success, indicating that in his opinion the Civil Air Patrol could be trained to take over the problem of finding, measuring, and isolating any contaminated area in a matter of hours where ground parties might well take days to do the job. His words were echoed by A. D. Warden of the ORNL staff who said he believed the source of radiation was located far easier by air than by ground search.

In addition to the dramatic new radiation survey role, CAP planes and crews demonstrated other capabilities during Operation Cue. During a 3-day period more than 70 scheduled missions were flown by CAP Cessnas, Navions, L–5's, L–16's, Howards, and Bonanzas. These included an airlift between Yucca airstrip, within the Nevada Test Site of the Atomic Energy Commission, and Las Vegas about 80 miles away. Ninety percent of all the newsreel and television film viewed at home or at local theaters and most of the still pictures in daily newspapers were flown out in CAP

planes. CAP also operated flights to Los Angeles to help get the story of the atomic open shot to the American public.

If this had been an actual atomic attack these flights could have been carrying critical medical supplies.

All aerial photographic missions performed by the civil defense photo group were flown in CAP planes or in Bell and Hiller helicopters loaned to CAP for the tests by the manufacturers.

These missions were controlled by means of CAP's own radio network set up under field conditions.

In one of the more graphic demonstrations of its ability to perform under the most trying conditions, 2 CAP planes were landed on a small stretch of gravel road 1 mile from ground zero on the day following the explosion. There in the shadow of a typical, 2-story American home reduced to shambles by the explosion the planes took on "survivors" and winged their way to Yucca airstrip and safety.

The civilian volunteers of the CAP demonstrated in several ways that they are ready, willing, and able to support local civil defense agencies providing aerial reconnaissance and photographic service, courier flights, evacuation missions, aerial supply, and radiation monitoring.

Figure 26.—The Busy CAP—The Civil Air Patrol, Nevada Wing, was a busy participant in "Operation Cue." In addition to removing simulated litter cases uncovered by civil defense rescue teams, the CAP furnished planes and pilots for aerial monitoring, transportation of aerial photographers and food, and for carrying press copy and photographs from the Test Site.

Civilian volunteers of the Civil Air Patrol can be proud of this new role—an assignment which could mean the saving of perhaps thousands of lives in the event of atomic attack upon the American homeland.

It is a role which may not be as dramatic as blasting enemy bombers from the skies but it certainly is one which would be of paramount importance should one of those enemy bombers elude our defenses and drop its deadly cargo on one of America's cities.

The following addresses beginning with p. 87, were selected from a transcript of preshot briefings for test observers at the Las Vegas (Nev.) High School Auditorium.

EFFECTS OF NUCLEAR WEAPONS

BY HAROLD L. GOODWIN,
Director, Atomic Test Operations, FCDA

A great deal of information has been released over the past several years on the effects of atomic explosions, yet many of these effects are still poorly understood by the general public. For that reason, the principal effects of a nuclear explosion are reviewed, with a brief discussion of factors of particular importance to civil defense.

This entire section is based on informaton available in published sources. There is a widespread but erroneous view that most information on the effects of nuclear explosions is classified, and hence is not available to the general public. Information that exists only in classified form generally is information which deals with refinements of weapons effects. A considerable amount of gross information on any major effect is available in a number of publications.

The best reference in this field is still the basic handbook, *The Effects of Atomic Weapons.* Despite the fact that this useful work was first published in 1950, queries daily to the Federal Civil Defense Administration indicate that it has not been widely studied or understood. A thoughtful reading will be of value to any person with civil defense responsibility. A revision, now in process, may be issued in the next few months.

Because of uncertainties that would exist in any attack with nuclear weapons, too precise a refinement of civil defense plans is undesirable. Such refinement produces a kind of spurious accuracy, which can be extremely misleading.

The uncertainties inherent in an attack situation are these:

(a) The power of an atomic weapon an enemy might use against any particular city. It can be assumed that an enemy is capable of producing nuclear devices of almost any desired power from a few thousand tons of TNT equivalent (kilotons) to many millions of tons (megatons). However, it is worldwide military practice to standardize on a comparatively few types of weapons. What standards an enemy chooses for nuclear devices must necessarily be a matter of conjecture. This means that city civil defense must have plans capable of meeting the situations caused by single thermonuclear weapons large enough to take out the entire city, and combinations of smaller weapons whose combined yields would produce the same effect; or single weapons or combination of weapons which might produce great damage without necessarily producing citywide devastation.

(b) By analysis of population and industrial concentrations within any target area, we are able to assume what we believe to be a logical aiming

point for enemy attack. However, we do not know how complete the enemy's information may be or whether his attack assumptions are the same as ours.

(c) We do not know for what altitude an enemy might set his fuzes. Variation of the altitude of a burst of a given power can modify considerably the effects-distance relationships particularly for weapons below the megaton range.

(d) It cannot be assumed that enemy bombing would be entirely accurate. An unknown value must be assigned for bombing error. This error could be caused by poor or faulty equipment, the "human" element in operations, or harassment of the enemy aircraft by our own defenses.

(e) It should also be recognized that much civil defense planning is based on an assumption which is known to be inexact. This is the assumption of symmetrical behavior of a nuclear burst—that propagation of blast and other effects is equal in all directions—as demonstrated by the concentric circles commonly used in target analysis. The concept of symmetry and the use of the resulting concentric circles for target analysis is most useful and, in fact, is the most practical basis available for planning. However, propagation of nuclear effects, particularly blast, would almost never be symmetrical over a target because of variations in the terrain, including the presence of built-up areas, and, to some extent, the behavior of the weapon itself. It would be almost impossible to accurately analyze the effects of terrain and built-up areas on blast propagation even if ground zero were known precisely. Hence, while civil defense is limited to the assumption of symmetry for lack of more precise data, it should be kept in mind that this assumption creates an initial margin of error in all planning.

These factors necessarily restrict civil defense planning to gross effects. For that reason, in considering the effects of a nuclear weapon, it is more practical to deal in round numbers than in precise numbers refined to several decimal places.

Phenomena of a Nuclear Explosion

The almost instantaneous release of energy by fission or fusion of atoms in a nuclear explosion is accompanied by the production of extremely high temperatures. The energy emitted covers a wide range of wave lengths from infrared through the visible to ultraviolet and beyond. Much of this radiation is absorbed by the air immediately surrounding the burst, with the result that the air becomes heated to incandescence.

The burst begins to appear after a few millionths of a second (microseconds) as a ball of fire. The energy continues to radiate and, as the temperature of the air through which it passes is raised, the ball of fire increases in size. After about one ten-thousandth of a second (0.1 millisecond), the temperature is about 300,000° C. At a distance of 10,000 yards the lumin-

osity would be approximately 100 times that of the sun as seen from earth in the case of a 20-kiloton burst.

As the ball of fire grows, a shock wave develops in the air. Soon the shock wave breaks away, and after the lapse of 10 seconds the shock wave has traveled about 12,000 feet. By this time the ball of fire has floated upward about 1,500 feet.

Nuclear radiation is emitted, starting at the instant of detonation and continuing for an appreciable time. For civil defense purposes, however, it may be considered that danger from this cause is essentially over within 90 seconds, with the greatest amount of radiation being emitted within the first few seconds. This radiation consists of highly penetrating neutrons and gamma rays, and less damaging beta and alpha particles which are absorbed quickly by the air.

Soon after the detonation of a dawn shot a violet-colored glow may be observed. It is believed that the intense gamma radiation causes ionization of the nitrogen and oxygen of the air. During a complex series of events, the excited nitrogen and oxygen molecules return to their normal state by emitting energy in the form of visible radiation. The radiation falls to a large extent in the violet region of the spectrum. This constitutes the violet glow.

As the ball of fire rises and loses its luminosity, a doughtnut-shaped cloud emerges. Occasionally some of the violet glow continues through this phase, and there is in addition noticeable color ranging from brown to peachlike tints. While some of this brownish color may be caused by dirt sucked up with the rising thermal column, the tints also occur in airbursts and are apparently due to nitrogen dioxide, a brown gas formed by the combination of nitrogen and oxygen at high temperatures. This transformation takes place at temperatures between approximately 1,700° and 4,700° C.

Because of its high temperature and low density, the ball of fire rises at a rate that very often surprises people whose previous experience with detonations has been limited to motion pictures taken at slow motion speeds. As the ball of fire rises, it is cooled. At first the cooling is mainly due to loss of energy as thermal radiation, but as time progresses the temperature is lowered as the result of expansion of the fireball gas, and by mixing of the gases with the surrounding cooler air. As cooling takes place, constituents of the rising ball of gases condense, forming water droplets and a metallic smoke made up of solid particles of varying sizes. In addition, if a device is detonated low enough for the fireball to touch the ground, a considerable amount of dirt and other material is vaporized and sucked up. Small solid particles of these materials separate out as cooling takes place.

At first, particles are carried upward by the rising fireball, but after a time they begin to fall. An ascending and expanding column of smoke

forms. It consists of water droplets, radioactive oxides of the fission products, and more or less debris. This column is the "stem" of the mushroom.

One intersting phenomenon is the formation of an icecap. This cap appears at the top of the "mushroom" and sometimes appears to flow down over the sides. The cap is composed of myriad small ice crystals caused when gases above the mushroom expand and are cooled, causing water vapor in the air to be converted to ice.

Blast Effects

An explosion generally depends upon the production of very hot gases in a restricted space with a consequent production of high pressure. A nuclear explosion is no exception. The very hot gases produced start to move outward toward the atmosphere where the pressure is lower. The great expansion which occurs then pushes away the surrounding atmosphere. This action initiates a pressure wave. The front of the wave compresses and heats the atmosphere through which it moves. Since the wave disturbance moves faster through air which is heated and compressed, the after portion of the wave tends to catch up with the front. As a consequence the wave front gets steeper and steeper, and within a very short period it becomes abrupt and may be considered as a moving wall of highly compressed air. This shock front on the pressure wave initiates a series of events that causes most of the damage to structures.

As the pressure wave propagates outward it tends to slow down, eventually slowing to the speed of sound in the surrounding atmosphere. This slowing is due to loss of energy. The same loss also lowers the effective pressure of the shock front. Behind the shock front the pressure drops until it becomes negative and a suction phase develops. This negative or suction phase follows the positive or overpressure phase.

Duration of the shock wave increases with distance from the burst. For example, in a 20-kiloton burst, the positive phase of the shock wave lasts only about one-half second at 2,000 feet, but lasts for a full second at about 7,800 feet.

Some test objects in Operation Cue were at a distance where they received 5 pounds per square inch overpressure from this particular explosion. An explosion of a different size would produce 5 psi at a different distance, and the duration of the shock wave would be different: a larger burst would produce a longer pulse; a smaller burst one of shorter duration.

When the shock front reaches the rear edges of a structure it spills in behind the structure and completely envelops it in the high pressure air mass. At this point, the blast wind becomes the predominant factor in tending to push the structure over or collapse it. This force is called the drag loading and can be roughly compared to the loading upon an object

in the airstream of a wind tunnel. Since the positive phase of the blast wave increases in duration with an increase in burst size, it can be seen that in the case of a megaton burst, there would be a considerably longer drag from a shock wave with a peak overpressure of 5 psi than would be the case in a 20-kiloton or "nominal" burst. This drag loading may greatly increase the damage to structures which have only partially failed as a result of the shock loading, and may be the principal cause of damage to objects such as vehicles and radio towers.

In view of the variations of pressure, distance, and duration of effect with variations in bomb power, it seems more practical from the civil defense viewpoint to use damage-versus-distance criteria for average conditions than to discuss damage in terms of specific overpressures. The A, B, and C damage zones described in civil defense publications are average damage-versus-distance zones.

The question is often raised whether the negative (suction) phase of an explosion causes damage. The answer is that it does. The arrival of the negative phase results in the lowering of the pressure on the outside of a structure below the entrapped normal atmospheric pressure inside the structure. The structure will therefore be stressed outwardly and a comparatively flimsy structure, already weakened by the positive phase loading may even explode. The effect on people fortunately is not analogous. There is little evidence that this negative phase would produce any significant number of casualties.

There has been some tendency to compare the dynamic loading from an atomic burst with wind loadings on structures. The effect is different, since wind is applied more gradually. It is true that wind gusts of hurricane force can load a structure rapidly, but even this loading is extremely slow when compared to the speed of loading resulting from a rapidly moving pressure wave.

There are other considerations that contribute to damage. For example, reflection characteristics, which may double or treble the load on the face of a structure, are not taken into account.

In *The Effects of Atomic Weapons* the yield of the so-called nominal bomb, equivalent to 20,000 tons of TNT, is taken as a model and extensive data are given for it. Scaling laws to allow prediction of the effects of bombs of other sizes are included. While some of the quantitative statements in the original volume are being corrected in the next revision, they are not of great significance from the civil defense point of view. Hence, for civil defense planning, these scaling laws may be applied for bursts of any size, including weapons in the megaton range. The basic equation for blast scaling is as follows:

$$\frac{r}{r_0}=\left(\frac{W}{W_0}\right)^{\frac{1}{3}}.$$

Here r_0 and W_0 represent the radial distance from and the energy of the reference explosion. Use of this equation is illustrated by a specific example.

During Operation Doorstep in the spring of 1953, it was announced that the device to be exploded was equivalent to 15 kilotons of TNT. It was also announced that the house at the far range, 7,500 feet from the explosion, was expected to receive an overpressure equivalent to 2 pounds per square inch. For the example, assume that a city civil defense director wishes to know the areas in which houses would be expected to receive approximately similar damage in his city from a burst of 8 times the power—say one of 120 kilotons' equivalent. The reference burst in this case is the one that took place in Operation Doorstep. Therefore, the radial distance of the house, 7,500 feet, is substituted for the figure r_0. The figure for 15-kiloton equivalent is substituted for the figure W_0. Since we wish to scale these data to a 120-kiloton burst, the figure of 120 is substituted for W. Solution of the equation is as follows:

$$\frac{r}{7{,}500}=\sqrt[3]{\frac{120}{15}}$$

$$r=7{,}500\times\sqrt[3]{8}=7{,}500\times 2=15{,}000 \text{ ft.}$$

(twice the distance for an 8-fold increase in bomb yield).

The time of travel of the shock wave is not generally understood by many persons. The concept of "duck and cover," which would still be of great value in case of attack without warning, is based on the comparatively large time interval between the burst and arrival of the shock wave at a given point.

It takes several seconds for the shock wave of a nominal bomb to reach a point 2 miles from the burst. A person who moved promptly at the first light of the detonation would have time to get under or behind a convenient piece of furniture, or other protection. At greater distances there would be even more time.

This time lapse between the detonation and arrival of the shock wave was graphically demonstrated to persons watching from the observer areas in the Test Site. The detonation takes place, a phenomenon without sound from the viewpoint of the observer. So much time elapses between the detonation and arrival of the shock wave that observers sometimes forget that the shock wave is on its way and the loud bang of its arrival finds them unprepared. Persons are frequently startled and have even been pushed off balance by the shock wave. The pause between a lightning flash and the thunder is comparable.

The question may be asked, how will one know when a burst has gone off if the sound does not arrive for some time? The answer is that the light from the explosion is its own warning. The light of a 20-kiloton burst

has been described as "a sudden increase in the general illumination, tapering off to normal after a lapse of a few seconds." This description, while somewhat ponderous, is accurate. To persons who have never seen an atomic detonation it can only be said that if a burst takes place over their city, they will know it. There is nothing quite like the light of a large nuclear burst.

Thermal Effects

Roughly one-third of the energy of an atomic burst may be released in the form of thermal radiation. Most of this radiation is released within a very short period of time, with the result that impact of the radiation on objects or persons is in the form of a transient "heat flash."

In a vacuum, intensity of thermal radiation would decrease according to the inverse square law. (One-fourth the value at twice the distance, $\frac{1}{9}$th the value at 3 times the distance, etc.) However, thermal radiation is also reduced by air absorption. The amount of heat applied at a given distance from a burst of a given size depends to a considerable extent on visibility, or the amount of haze in the air at the time.

The effect of thermal radiation from a nuclear burst is commonly expressed in calories per square centimeter (cal./cm.^{2}). To predict the number of calories per square centimeter resulting at a given distance from a burst of a given size requires rather exact information on the amount of haze present. Since the amount of haze depends on weather conditions, and the amount of dust and smoke in the air, it is impossible to predict thermal effects from a burst over a city with a high degree of accuracy. However, the visibility factor becomes of less importance as weapon size increases.

In discussing the possibility of damage or fire from thermal radiation, two factors are of importance. One is quantity of thermal energy, and the other is duration of application. This may be illustrated by two examples. If the intense flame of a blowtorch is passed over a sound wooden surface, the wooden surface will not ignite. If the blowtorch is held at one spot on the wooden surface for a sufficient length of time, the wooden surface may be made to burn. By the same token, if a person passes his hand quickly enough past the flame of a blowtorch, he will not be burned. If his hand moves slowly, the degree of burn will depend on the length of time heat is applied.

Since the heat flash from a nuclear burst passes rapidly, it is not applied for a sufficient length of time to ignite massive surfaces of sound or painted wood at distances corresponding to the C and D rings of blast damage of a nominal burst. Within the A and B rings there is some question about how much ignition actually takes place.

Closer to the burst, there is a probability that some fires set by thermal flash are blown out by the blast wave which follows, but visual observation of these effects is unreliable. For example, in watching television and newsreel motion pictures of the house nearest ground zero in Operation Cue, some people received the impression that the thermal flash set the front of the house on fire and that the blast wave blew the fire out. Frame by frame analysis of the pictures shows clearly that this was not the case. The thermal flash struck the front, causing charring. A "smoke" developed, and a thermal convection current caused by the heating of the air lifted this smoke up the face of the house. The phenomenon caused by the thermal effect was essentially over before the shock wave arrived. Frames of the motion picture taken during this interval before the shock wave struck show the last of the smoke dissipating, and no sign of flame.

Other experiences do show, however, that where readily ignitible materials exist, fires set by the thermal flash may continue to burn and may develop into large fires.

The effect of thermal radiation on easily ignited materials, commonly called kindling fuels, was graphically shown in the FCDA film, "The House in the Middle," which used automatic film taken for the Department of Defense. The project in which these films were taken demonstrated clearly that unsound wood, which has been exposed to the weather for some time and is consequently rotted or splintered, is easily ignited by thermal flash. Rubbish, particularly paper, also ignites from thermal radiation. Interiors of the little test houses caught fire when easily ignited furniture upholstery or curtains were struck by thermal radiation.

The main lesson for civil defense is that fire vulnerability from thermal radiation can be reduced in direct proportion to good housekeeping within a city. Good housekeeping includes keeping streets and alleys clean. It means keeping wooden structures, including fences, painted.

The value of paint as protection against thermal radiation is a subject of frequent questions. From the civil defense point of view, all paint is good if it protects a structure from weathering. Paint itself, even oil base paint, does not seem particularly susceptible to ignition. Generally, a protective film of paint is so thin that, at distances where ignition is likely, the entire film would be charred.

It is true that color has a direct bearing on the amount of thermal radiation absorbed. The lighter the color, the less the absorption. While there is undoubtedly a critical range where the degree of absorption of thermal radiation by paint is significant, this range is so narrow that there seems to be little practical reason for selecting a color because of its ability to reflect thermal radiation.

Color characteristics also apply to clothing. It is difficult to say how many inventors have developed suits or coveralls designed to protect against

thermal radiation. Designs have been submitted to FCDA which vary from simple white cotton garments to elaborate suits with asbestos lining. Some designs have used metallic foil to give a highly reflective surface. The designers of such suits, however, have overlooked a significant consideration: If one knows that a burst is coming, even a few seconds give time enough to get under cover sufficient to protect against thermal radiation. If one does not know that the burst is coming and is caught in the street, it is too late to put on a suit, since the thermal radiation, for all practical purposes, appears and is gone at the time of the detonation.

Generally, anything dense enough to cast a shadow will provide protection against direct thermal radiation. This applies equally to a sufficient thickness of paper and a concrete wall. While the paper itself might catch fire, the person behind it would be protected during the actual heat flash.

It may be considered that thermal radiation travels in straight lines from the smaller nuclear bursts. However, it can be reflected around corners just as light can be reflected by shiny surfaces, and is "scattered" by the atmosphere in much the same way. When reflected off rougher surfaces, such as concrete walls, it would lose some of its effectiveness, but would be reflected nevertheless. This factor should be taken into account in shelter design.

There is no difference between a fire set by thermal radiation and a fire set by any other cause. The fires would be fought in exactly the same way. The main difference is that there would be more fires in the event of nuclear attack, but even this difference can be reduced by preventing the thermal radiation from reaching kindling fuels. This can be done by removing such fuels from positions where they could "see" a burst, or where practical, by providing screening between them and a possible burst.

In cases where sufficient warning is received to allow the populace to get under cover, even cover which would not be effective against blast, there should be comparatively few casualties resulting from direct thermal radiation. In situations where people were caught in the open, there would be a considerable number of burn cases resulting from thermal radiation. From the medical viewpoint, burns produced by nuclear weapons differ in no respect from burns caused by any high intensity heat of short duration. The treatment is the same.

The duration of the heat flash from a nuclear burst varies with the size of the bomb. The total amount of heat produced is directly proportional to the energy release of the weapon. A bomb in the megaton range would have a significantly longer thermal pulse than one in the kiloton range. It would even be possible for a person with fast reflexes to cut down the total thermal radiation reaching his skin by turning away or by diving behind something if a thermonuclear bomb should burst without warning.

Nuclear Radiation—Initial

At the moment of fission or fusion in a nuclear weapon, great quantities of nuclear radiations are released. In an exploding atomic bomb about 6 percent of the energy is delivered in the form of initial nuclear radiation. This radiation is emitted over a relatively short period of time; within a minute and a half it is essentially gone, leaving no significant residue. Initial or "prompt" radiation may be likened to a radiation flash or wave. It should not be confused with residual radiation produced by fallout.

Alpha and beta particles are emitted by initial radiation but are of no particular civil defense significance. Gamma rays and neutrons can, however, cause casualties among persons who are not properly shielded.

Absorption and scattering of gamma rays by the air is so effective that casualty-producing doses from initial radiation would be limited to the area of major blast damage. Even within this zone, however, a sufficient thickness of concrete or earth would provide adequate protection. While any dense material of sufficient thickness, including concrete, iron, and lead will provide shielding, the cheapest and one of the most effective shielding materials is earth. The simplest way to provide earth shielding is to get below ground. Persons with belowground basement shelter, for example, generally have adequate earth shielding from initial radiation. In shelters placed according to civil defense specifications, persons in basement shelters would not be expected to become initial radiation casualties even at ranges so close to the burst that death might result from other causes.

The effect of gamma radiation on objects is so slight and occurs in such special cases that it is of little significance to civil defense.

Neutrons, comparatively massive uncharged nuclear particles, have a somewhat different effect. They are the atomic bullets on which fission depends in the first place. Like gamma rays, they are capable of producing casualties. However, because of their interaction with the air, neutron fluxes of significance would not be expected at distances greater than those of gamma rays.

As the size of weapons increases, the effects of initial nuclear radiation become proportionately of less significance, since blast and thermal effect tend to outrange both gamma rays and neutron effects.

Within an area where sufficient neutrons occur, however, materials struck by neutrons may have radioactivity induced in them. The nature and intensity of this induced radioactivity depends not only on the quantity of neutrons causing it, but on the nature of the material itself. The radioactivity is due to the production of radioactive isotopes. Some isotopes have a radioactive half-life measured in minutes or less. In others it is days, or even years.

For example, iodine 131 is a common radioisotope of iodine. This isotope has a half-life of 8 days. That is, at the end of 8 days, ½ of the radioactivity

in a given quantity of iodine will be gone. At the end of another 8 days, ½ of the remaining activity will be gone, and so on.

Radioactivity induced by neutrons in the vicinity of the burst is of little civil defense significance. In general, such induced activity would result only in places so close to a burst that they would not be accessible for many days because of rubble and damaged buildings. Further, most of the induced activity would occur only in areas of such complete damage that there would be little point in trying to get to them anyway. And, in the third place, the dosage levels from such activity would not usually be high enough to constitute a problem, particularly after a little time had elapsed.

Dosages of radiation are measured in roentgens. The lethal dosage is generally given at 600 roentgens. At this dosage and above, few would be expected to survive. The median lethal dosage—that is, the dosage at which ½ the persons exposed would be expected to die—is generally given as 400 roentgens. The median sickness dose—at which ½ of the persons exposed would be expected to become ill—is generally given as 200 roentgens. Below dosages of 100 roentgens, very few persons would be expected to become ill. Below 50 roentgens it is unlikely that any cases of illness would result. Slight blood changes may be detectable at 25 roentgens, but these are apparent only to pathologists.

The dosages given above apply to acute irradiation of the whole body. Dosages greatly in excess of these amounts are often given by radiologists to limited portions of the body for the treatment of such diseases as cancer.

An important factor in calculating dosage is time. Radiation survey instruments are called rate meters, since they measure radioactivity at a "roentgen rate." The intensity of radiation is usually measured in roentgens per hour, or in milliroentgens per hour. A milliroentgen is 1/1000 r. An understanding of this factor is of particular importance in civil defense. It might be necessary, for example, for a rescue team to take people out of rubble in an area where the measured rate of radioactivity was in excess of 100 roentgens per hour. In oversimplified terms, the team could work in the area for a period of 30 minutes and receive a total dose of only 50 roentgens. Fifteen minutes' work in such an area would result in an exposure of about 25 roentgens, and so on. The rate meter is supplemented by a dosimeter which measures total or accumulated radiation dose.

Nuclear Radiation—Residual

When a nuclear device is exploded, atoms are not totally destroyed. Instead they are fissioned or fused into other atomic species. When atoms of uranium or plutonium are fissioned, the atomic species that result are called fission products. These fission products eventually fall to the ground and constitute one source of residual radiation.

In addition to the fission products, some portion of the bomb fuel remains unfissioned. This fuel is blown into tiny particles and eventually it too falls to earth, constituting another element of the contamination.

In an air burst, where the fireball is substantially above the ground, unfissioned fuel and fission products constitute nearly all of the radioactive material. They are sucked up in the fireball and, because of the small size of the particles, they drift to earth slowly, over a considerable period of time. They are widely scattered by the winds. As a consequence, fallout from an air burst does not constitute a civil defense hazard.

On the other hand, when the detonation is low enough so that the fireball touches the ground or is actually on the ground, great amounts of earth and other materials are drawn into the rapidly rising fireball. Much of this material serves as a carrier for the finer particles of highly radioactive material, since compared to the radioactive particles, the material is coarse and tends to fall rapidly while being carried along with the wind. The amount of earth and other materials sucked up by the fireball will depend on the height of burst and yield of the device. When a weapon of megaton yield is exploded close to the ground, hundreds of tons of material may be sucked up later to bring down radioactive particles.

Atomic weapons like those fired at the Nevada Test Site produce contamination which extends for only short distances. Dangerously active areas are confined to the test site, and even then such dangerously active areas are usually confined to the immediate vicinity of ground zero. The dimensions and shape of the contaminated zone depend on the wind patterns. Characteristically, there is an ellipse with maximum activity closest to the point of detonation and minimum activity at the far end.

The activity of radioactive particles begins to drop off at the instant following the detonation. This decrease in radioactivity is called decay. Many fission products decay so rapidly that there is, for practical purposes, no radioactivity left in the particles by the time they have fallen to earth. Other fission products and isotopes continued to be active for long periods of time.

No two fission products behave exactly alike. For example, silicon, a major constituent of soil in most parts of the world, can be converted by neutron bombardment into a radioactive isotope, silicon 31. This isotope has a half-life of less than 3 hours and its activity is limited to emission of beta particles. Direct exposure of skin to sufficient beta activity can cause what is known as a beta burn, but shielding against beta activity is relatively simple. For example, monitors in automobiles would not be exposed to beta activity since the thin metal would provide sufficient shielding. For low-energy beta particles, clothing also provides some shielding.

On the other hand, from the sodium generally present in soil, neutron bombardment would produce radioactive sodium 24 with a half-life of 14.8

hours. Sodium 24 emits beta particles as does silicon 31, but, in addition, it also produces gamma rays.

The unfissioned plutonium or uranium used in nuclear explosions would present still a different case. These radioactive elements have extremely long half-lives. For all practical purposes, it may be considered that their radioactivity lasts indefinitely. This very long life, however, also means that the amount of radioactivity they produce is small compared with that of the more intense and shorter-lived fission products.

The whole complex of neutron-induced isotopes, fission products, and unfissioned materials can present a definite civil defense hazard from a ground burst. The extent of the hazard would, of course, depend on the yield of the device and on wind patterns.

Fortunately, there are protective measures which can be taken. The first measure, although not always the simplest, is putting distance between people and dangerous contamination. Distance does not always mean getting out of a contaminated area. It may also mean getting as far away from contamination as possible within a structure.

Shielding is also effective against radioactive contamination. Going belowground is generally the simplest method of obtaining shielding. Taking cover in a basement or cyclone cellar, for example, would reduce exposure appreciably. That is, exposure of persons in a basement might be reduced to 10 percent or less of the exposure they would receive on the ground outside the house. Persons caught in a highly contaminated area without other shelter could improve their situation materially by "digging in." A foxhole or trench that allowed people to get completely belowground would have a relatively high degree of effectiveness.

The third method of protection against radioactive fallout is decontamination. The possibilities of decontamination apparently are not widely understood. Fallout materials are particles of matter. In effect, they are finely divided dust. Apart from their radioactivity, they behave like dust and can be removed like any other dust.

Washing a contaminated object generally will reduce its radioactivity. Ordinary soap or detergent and water is good enough. The radioactive particles are carried off in the wash water, which must then be disposed of if sewer systems are inoperative. Of course care must be taken not to flush the contamination into places where people may gather. A vacuum cleaner is also a good decontamination device. The vacuum cleaner simply sucks up the contaminated dust. Of course the contamination is then concentrated in the vacuum cleaner container, which must be disposed of by placing it at a safe distance or by burying.

If houses were to be contaminated by fallout from an enemy burst, a heavy rainfall would provide some decontamination of the roof. Paved

areas could be decontaminated by flushing with a hose if sufficient water were available.

Another excellent decontamination tool for some uses would be a bulldozer or scraper. Contamination would be confined to the upper layer of soil, and a bulldozer or scraper could push it aside. True, the contamination would remain in the removed earth, but it could be pushed far enough away to leave an area relatively free of radioactivity.

During peacetime operations like those that take place at the Nevada Test Site, protective clothing is commonly worn. This clothing has no mysterious properties. It consists of coveralls, canvas booties, gloves, and headgear of some sort. Often a surgeon's cap is worn. This clothing is provided only as a convenience to the operator. If by chance he should pick up contaminated matter from a firing area, most, if not all of it, would be removed with the removal of his protective clothing. Thus, the operator would not need to send his own clothing to the laundry. Headgear is worn to keep contaminated dust out of the hair, the hardest part of the body to get clean. When a person does become contaminated in spite of his protective clothing, the contamination is removed by a shower. In extreme cases, more than one shower may be necessary. However, in spite of the large numbers of people who work in contaminated areas within the Nevada Test Site, situations where decontamination becomes necessary do not often occur.

Decontamination of vehicles is fairly common. This is because contaminated dust is picked up on the feet of personnel and left in the vehicle. Sometimes the vehicle itself picks up enough contaminated dust to require washing down. Greasy or oily parts of vehicles or other objects present a more difficult decontamination problem since grease and oil tend to retain dust. In such cases, it is often necessary to remove the grease and oil, sometimes by the use of steam. Sometimes vehicles are simply put aside to cool, and natural decay reduces the contamination to safe levels.

It should be noted that personnel of the test organization work freely in contaminated areas as required, although they must stay within the maximum allowances for radiation exposure established by the test organization. Since the hazard of fallout is measured in roentgens per hour, it is only necessary for personnel to keep track of the length of time in which they work in a radioactive field in order to avoid exceeding the allowable dose.

The desire of project personnel is to avoid being burned out. This ominous phrase simply means that the burned-out person has reached his maximum allowable dosage for the series according to test organization standards and is no longer able to work in contaminated areas. However, he can resume activities in the next series. A comparison of these standards with disaster standards shows the conservative industrial approach to radia-

tion exposure: Where the maximum allowable dose within the test organization is 3.9 roentgens over approximately a 13-week period, in a civil defense emergency an individual might have to accept 25 roentgens per day for a period of several days, if the situation required. However, these higher doses should be accepted only where the exposure is clearly warranted. (The general maxim for civil defense, as for all other agencies dealing with radioactivity, is that the best amount of radiation exposure is none at all.)

PLANNING AND CONDUCTING NEVADA TESTS

BY DR. ALVIN C. GRAVES, *Scientific Advisor to the Test Manager*

In general, all nuclear field test experiments are designed to answer two types of questions: How did the device operate, and what were the effects?

In the first category are experiments to answer what happens just before and just after the nuclear explosion begins, to determine the explosive force and efficiency. These are nuclear diagnostic experiments.

In the second category are experiments to get data on neutrons, gamma rays, thermal radiation, and blast released by detonations; tests to determine how best to attack a given structure with atomic weapons; tests of the protection against atomic explosion afforded by structures, equipment, textiles, shelters, and the like; and biomedical tests to determine the effects on living matter.

Complex and intricate considerations are involved in planning and conducting these tests here in Nevada.

Each Nevada test must be justified as to its safety, but before then it must have been justified as to its importance to the Nation. Only tests which are vital to national atomic programs, only those which contribute directly to the vital interests of this Nation and of the free world are admissible. It may be seen that the first consideration in planning and in operations must be to obtain the technical data which justified scheduling the shot.

The major limitation on use of a continental test site is public health and safety. The protection problem begins with the thousands of participants and official or public observers who may be on or above the Test Site, extends to the general public in the nearby region, and to a much less degree the public throughout the Nation. The criteria, controls, and procedures which have been developed to assure minimum public exposure enter into almost every step of planning and operations.

With the passage of time new ideas originate in the weapons laboratories, new requirements for weapons are posed by the military, or important new questions are asked as to design, efficiency, or effects. As the various test projects accumulate, a future series is scheduled tentatively and only very generally as to possible season of a year.

The progressive frequency with which basic ideas have been generated, and basic questions raised in weapons development and effects, is indicated by the schedule of detonations in Nevada and in the Pacific. The time

schedule and the number of tests since 1950 should also indicate the rate at which questions have been answered.

Trinity Site, New Mexico, July 1945 (1)
Bikini Atoll, mid-1946 (2)
Pacific Proving Ground, spring 1948 (3)
Nevada Test Site, winter 1951 (5)
Pacific Proving Ground, spring 1951 (4)
Nevada Test Site, autumn 1951 (7)
Nevada Test Site, spring 1952 (8)
Pacific Proving Ground, autumn 1952 (more than 1)
Nevada Test Site, spring 1953 (11)
Pacific Proving Ground, spring 1954 (more than 2)
Nevada Test Site, spring 1955 (14 scheduled)

It is perhaps interesting to note that part of the present 1955 series was planned by winter 1953. An autumn 1953 series was scheduled. It included a major test which established the calendar requirement. As a result of a prior test in the spring 1953 series, Los Alamos in early May recommended the addition of an eleventh shot to that series instead of the major test planned for the next autumn. Within 30 days the shot had been fired and the data were back in the laboratory. Successful accomplishment of this shot removed the major requirement for the autumn series and it was postponed, the postponed shots providing the nucleus for the 1955 series.

The sorting out of test proposals for a specific series may begin a year in advance. Usually about 8 months in advance plans are sufficiently firm to begin the procedures essential to starting construction and organization. At about 5 months programing begins with selection of an operating period and determination of scheduled total number of shots.

The series schedule is established on a basis of when a test and all of its related experiments must be ready. In the present series, we have frequently had 2 ready for firing on the same date, and it developed that we had 3 ready for firing on the same date. In arriving at probable length of a series, consideration must be given to the probability of continuing weather delays, and to the time that personnel may be asked to remain away from home laboratories or away from their homes. Scheduling must provide for rotated use of firing areas in keeping with probable wind directions, and consider the possibility that one shot will contaminate the firing area of a later shot.

In programing acceptable tests, consideration must be given to factors such as the limitations imposed by public safety on use of a continental site. These involve weather, maximum explosive force permitted, explosive force predicted vs. type of positioning of the device, type of soil at the target site or the advisability of soil stabilization, the materials which

will be in the device and the materials in a tower, and the probable maximum offsite fallout as related to the public exposure guide.

Also a determining consideration at the programing stage are the factors of technical requirements and the possibility of technical success. Technical requirements determine whether it is a tower, air, surface, or underground burst; largely determine the height of burst even among air drops; and determine the hour of day. Entering into this picture is the elemental question of whether an experimental device can be developed to answer the vital question posed and still be admissible to continental testing.

There are at least nine developmental purposes served by full-scale nuclear tests. One of these is to assure the adequacy of a weapon before it enters the national stockpile. Only in this instance would the detonation necessarily be of a weapon as such. In most instances, an experimental device is designed. The device tested will be simplified as much as possible to answer the basic question, it will minimize the expenditure of active material, and it is seldom a useful weapon design. The information obtained by its testing will, however, immediately or eventually affect the design of stockpile weapons and improve the stockpile position.

Our information people have distributed to you a schedule of all shots fired here in Nevada. From this list and from previous supplementary releases, you will note that past tests have included air drops with bursts ranging from less than 1,000 feet to more than 30,000 feet; cannon-fired air burst, towers from 50 feet to 500 feet, surface, and subsurface placements. The type of positioning is dictated by the type of knowledge desired; the height of towers is dictated by public safety criteria.

In comparison with a tower shot, an air burst is easy and comparatively inexpensive, although individual experiments are often more difficult. It has the major advantage of resulting in no significant contamination onsite or of fallout offsite. An air burst is used whenever the desired knowledge—either diagnostic or effects—can be obtained.

However, there are times when we must know in advance the exact position of the device to fractions of an inch and the precise time when a detonation will take place to millionths of a second. It may be necessary to turn on a piece of equipment at a second before, or a second after, a detonation. It may be necessary to place an instrument at a specified distance from a device—sometimes very close to it. When there are such requirements, a static test is needed and the device is mounted on a tower. Certain questions require surface or subsurface positioning. Limited yield devices designed for the purpose and meeting very strict criteria related to public safety may then be used.

In tests close to the ground, tons of dirt are sucked up into the cloud and there may be heavy fallout. In an effort to reduce the amount of dirt and more closely approximate the nature of a high burst, we have progres-

sively increased the height of towers. At Trinity the height was 100 feet. We have since used towers of 50, 200, and 300 feet, and in this series we have used 3 of 500 feet, 1 of 400 feet, 4 of 300 feet, and still have 2 unused towers of 500 feet. All of the results of the use of higher towers have not been fully analyzed—for instance the contribution of the increased volume of tower material to nearby fallout—but the record of offsite fallout during the series would indicate they have proved their worth. We are continuing to study the feasibility of towers of greater heights and are now considering design of a 300-foot tower on which a 500-foot tower can be mounted, for a total height of 800 feet. We are also now looking seriously into the feasibility of using anchored balloons as detonation and equipment mounts.

The nature of the soil under a tower can materially affect the amount of nearby fallout. Very light soil particles, like those in the Frenchman Flat dry lake bed, seem to float off in the mushroom cloud descending very slowly and at greater distances, after their radioactivity has decreased materially. On one test in this series we will use asphalt in a test of the value of soil surface stabilization. We think the asphalt will hold the soil together—resulting in lumps more than particles—and that these lumps will remain on the ground or will descend very quickly to the Test Site or nearby bombing range. This stabilization test should not be confused with the use of a large asphalt surface on the April 15 shot for study of blast effects.

Related directly to the question of public safety from flash is the time of day when a shot is fired. If technical requirements permit, shots are fired in daylight and there is little concern over flash. Experiments involving photography usually require darkness. For this reason the immediate predawn hours are used when there is sufficient darkness for experiments, followed shortly by daylight to facilitate postshot operations. A majority of Nevada shots is fired at predawn.

As I have indicated the planned explosive force of the device is of major importance. The explosive yield of devices in Nevada has ranged from less than 1 kiloton to considerably less than 100 kilotons. Obviously, we do not test here the big "atomic" devices or the so-called H-bombs, ranging as they do from hundreds of kilotons for atomic bursts to megatons for thermonuclear bursts. We have very strict criteria governing the yield permitted for air bursts, for towers of varying heights, and for surface or subsurface placements. As I have said, we usually test experimental devices out here. Our predictions in such cases are usually for a range of yield, for instance from 15 to 20 kilotons, and in our safety planning we would use an upper limit of yield.

I might recall here that prior to the present series we answered a press inquiry by stating flatly that guided missiles as such would not be tested during this series. We have not tested a guided missile, and will not, in this series.

With these questions answered satisfactorily, consideration proceeds to factors such as structures and instrumentation required, technical and service support requirements, and division of firing area real estate and of the air over the Test Site to meet the needs of the various experiments and of the various added training and indoctrination programs.

The ground firing area around an airdrop zero point or a tower site is a fairly extensive piece of desert real estate, but with the use of tests for many purposes other than nuclear diagnostic experiments there has developed a considerable problem of space. Complicating the problem is the requirement that a majority of experiments must be upwind from the detonation to avoid radioactive fallout contamination.

The ground is divided into sectors, such as: Diagnostic sector; civil and military effects sectors; military materiel display sector and an observation and maneuver sector for participating troops; and in the open shot, a display sector for civil defense and a field exercise sector.

Soon after a preliminary schedule is fairly firm, the design and construction of specialized instrumentation begins in home installations, or elsewhere in educational or industrial establishments. Preliminary laboratory calculations and experiments, and the design of the nuclear device itself, are undertaken. Construction of technical facilities then begins.

The final schedule of shots is proposed perhaps 2 months before the series, including the technical and public safety justifications for each shot, and Presidential approval obtained for the expenditure of fissionable materials.

A similar buildup progresses in many places. The Armed Services plan their experiments, troop training programs, and allocation of aircraft, and support services, these activities reaching out to a multitude of service laboratories and other installations, and to private contractors. FCDA likewise has to start early on arranging for, and scheduling its experiments and training programs.

Obtaining the necessary security clearances for participating personnel is itself a factor requiring a considerable lead time in scheduling.

The buildup of activity in Camp Mercury and on Nevada Test Site begins with start of construction months before the first shot. Camp Desert Rock begins building up about 2 months before a series. Indian Springs Air Force Base has a somewhat later influx.

At about minus 1 month scientists and technicians involved in early experiments move to Nevada to supervise final construction, and installation of the equipment for their experiments. Final installation, wiring, and checking of instruments is supposed to be accomplished by minus 2 days, but may continue into the night before a shot.

The formal operational period of a series begins 2 to 3 months before the first shot. As of that date, the test manager takes over responsibility

for all test operations in Nevada, retaining the responsibility until about a week after the series end.

Throughout the week preceding any shot there is a progressive increase in activity. A series of signal runs is conducted to help technicians determine the readiness of their experiments. On some air burst tests there is a dry-run drop of high explosive. If troops are to have a field maneuver, there is a dry-run maneuver about shot day minus 2. Obviously, at some pretest time the experimental device is assembled and positioned for firing.

The initial go-or-no-go evaluation meeting is held the morning preceding shot day. It determines the readiness of essential experiments and results in preparation of a go-no-go list to govern any last minute determination of whether to fire based on readiness or functioning of experiments. If there is a probability that all key experiments will be ready and if the preliminary weather forecast is generally acceptable, the specific shot operation gets underway.

Starting the operational sequence includes such items as advising distant air bases they may prepare to launch bombers participating in air crew training, or preparing in Washington to take off with a flight of Congressional observers or, as on the April 15 test, flooding a lake. Complications are many if the shot is subsequently postponed.

Final preparations go forward on all fronts following the morning meeting. These include clearing the technical area and control point of all nonauthorized personnel and thereafter maintaining individual record checks to assure that all personnel are out by shot time.

A much more definitive meeting is held the evening before a shot. It includes a final readiness report on experiments, aircraft, and maneuver programs. It is essentially, however, a weather evaluation meeting. If there are good indications that meteorological conditions will be acceptable, for technical experiments and for onsite safety, the meeting progresses to consideration of weather and public health. These evaluations and considerations remain the background for further evaluations throughout the night—again related primarily to meteorology.

There is a final weather evaluation at about minus 1 hour based on minus 1½-hour data, which is supplemented by a wind run concluding at minus 15 minutes.

The single, major factor at zero hour or any time following zero hour with regard both to successful conduct of the technical operation and to blast and radiation fallout is weather.

The obtaining of scientific data, the operations of a bombing plane and scores of other aircraft, the direction and intensity of blast, the success of the troop operation, and the direction and intensity of radioactive fallout are all dependent on such factors as precipitation, cloud cover, temperature, temperature inversions, and wind directions and velocities.

It is essential that forecasters predict within small margins of error the direction and velocities of winds from ground surface upward to high altitudes. This is particularly difficult at ground surface in the mountain-surrounded basin used for a firing area, where winds will circle the compass in a few moments.

In order to obtain comprehensive data, the U. S. Air Force Air Weather Service has established a weather unit at NTS. It receives reports on hemispheric conditions and on more localized conditions. To further pinpoint conditions locally, a network of stations has been established in a complete ring around the Test Site. These include stations at Furnace Creek, Fresno and Needles, California; at Reno, Tonopah, Round Mountain, and Caliente, Nevada, and at St. George, Utah. In addition to these, both regular and supplemental data are furnished by regular U. S. Weather Bureau and USAF stations.

New observation stations, new equipment, faster communications, and new procedures have resulted, this series, in quite accurate forecasting of wind directions and velocities for zero hour and for several hours thereafter.

While on this subject, I should point out that the "weather" we wait for is not necessarily the same weather that tourists seek in a resort city like Las Vegas. In late winter and spring the normal wind direction is out of the northwest directly across Camp Mercury, Indian Springs, and the Las Vegas area. When a front passes, the wind may for a brief period come out of the southwest, blowing across Lincoln Mine and the Pioche-Caliente-Panaca area. Only very rarely—and usually for only a brief period—does it blow toward open areas to the east-southeast, to the north, or to the southwest. So, we are waiting for unusual weather as far as wind direction is concerned.

I have sketched the purposes of tests, the considerations involved in planning and firing a shot, and something of the schedule. Let's consider now the open shot, the shot in which you are interested.

This will be the 13th shot in the spring 1955 Nevada series, and the 44th continental test.

It is primarily a diagnostic test, although it is being used for military and civil effects experiments, for the civil defense open shot project, and for both troop and air crew training.

The detonation will be of an experimental device—you will be inaccurate if you describe it as a weapon or seek to pinpoint a military use for it—designed by Los Alamos Scientific Laboratory.

It will be a 500-foot tower shot in Yucca Flat. This of course underlines the fact that the device will be surrounded by instrumentation, that we want to know what happens in the microseconds before, during, and after detonation.

It will be at 5:20 a. m. Pacific daylight time, or approximately ½ hour

before sunrise, if the shot is fired Tuesday. If the shot is fired Wednesday, April 27, or up to April 30, it will be at 5:15 a. m. This means of course that many photo process experiments are included.

There will be 65 major associated experiments, divided into 9 for military effects, 16 for Los Alamos diagnostic experiments, 1 diagnostic experiment for Livermore, and 48 for civil effects, including civil defense.

This is the test during which we will try out the theory of soil stabilization under the tower. There is an asphalt surface over a circle of 600-foot radius, consisting of a 6-inch stabilized base and a 2½-inch road asphalt surface.

The ground area will be somewhat crowded with experiments, display areas, and people. There will, for instance, be in excess of 2,500 military people in 57 tanks, trenches, or observation areas, and approximately 30 civil defense workers in forward trenches at shot time.

The air will be somewhat crowded with approximately 80 aircraft flying training, technical, and support missions. These include training flights from far distant bases.

There will be no rockets laying a smoke grid and no instrumentation canisters. There will be the usual preshot high explosive detonations as part of the blast prediction procedure. These 2,400-pound shots will be at minus 2 and minus 1 hour at a point 4 miles north of ground zero.

We will try to keep you posted on the long range weather outlook, but please understand that such long range reports are not very reliable.

On Monday morning we will have our go-no-go meeting. We anticipate that all experiments will be ready. At this meeting we may find the weather outlook discouraging and so order a 24-hour postponement. If there is any possibility for acceptable weather, we will go ahead. The Monday morning evaluation will not be very definitive as far as weather is concerned inasmuch as it is based on shot-hour-minus-36-hour data.

If we go ahead, we will have a further evaluation about 9:30 Monday evening. Evaluation of weather at this time is fairly definitive, although of course not final. We will study the forecast wind direction and speeds at all levels.

The criteria for a tower shot of above nominal yield, even on a 500-foot tower, are quite strict. What we will look for is a pattern of relatively low wind speeds, with considerable horizontal shear, blowing toward open country between communities. Under such circumstances, heavy fallout would be on the Test Site and the nearby bombing range; fallout of lower intensity would be on unoccupied land near the bombing range and by the time fallout reached occupied communities it would be well within our guide of 3.9 roentgen per year biological dose.

We are fortunate in one respect in that prior shots have not resulted in any sizable fallout on any community and we will thus have more leeway

in selecting wind directions. I want to stress that the normal wind pattern at this time of year is to the south-southeast or south, and the usual shift is to the northeast, and these are seldom acceptable directions for the larger tower shots.

If the evening evaluation is satisfactory, we will proceed. About one hour before the shot—or about 4:20 a. m.—we will study reports from nearby and onsite weather stations to determine if the forecast is verifying and what the existing weather pattern is. Weather reported at that hour or the trend indicated usually will persist through shot time.

There are actually a considerable number of reasons for postponing a shot even after the evening evaluation meeting has decided to go ahead. I will discuss some, but not all.

It is seldom that all of the multitude of experiments are satisfied on a shot—because they were not ready, because of malfunctioning, or because of weather and shot effects. A shot is not fired, however, if a key experiment vital to the success of the shot will not be successful for any reason. Built-in safeguards can automatically stop a detonation if certain key experiments are not functioning at any second up to detonation. This occurred on a spring 1952 shot.

Any unfavorable change in the forecast wind direction or velocity would result in postponement. The formulae for predicting the intensity and location of significant fallout, onsite and offsite, must be matched to the varying weather forecasts throughout the night. The conservative new guide to public radiation exposure—3.9 roentgens per year biological dose—is the determining factor in evaluating offsite fallout forecasts. If there are any indications that fallout from the present shot will cause exposure approaching that figure at any inhabited nearby point or if new fallout plus fallout from a previous shot in the series would bring the total near that figure, the shot will be postponed.

Related to both technical and safety considerations are the factors of cloud cover and atmospheric moisture. Clouds can prevent air operations, including key experiments. Any indication of significant precipitation over the Test Site or nearby region could result in a postponement. Precipitation at more than 200–300 miles is not a major factor, because by then radioactivity in the cloud has greatly decreased.

Any malfunctioning of a key aircraft could cause a postponement.

Forecasts of the intensity and location of blast waves are made with each weather forecast. This factor could cause a postponement if there was a firm forecast that high blast levels would be recorded in communities.

All individuals must be checked as having cleared the forward area. If a single person is unaccounted for, the shot will be delayed.

Preshot consideration is given to the flash effect from the viewpoint of

issuing the necessary public warnings. This factor would not cause a postponement.

If all of these factors work out favorably Tuesday morning, we will have a shot. If they don't we will postpone until a morning when they do work out.

Here in the Las Vegas atmosphere, you might want an analysis of your chances to see a shot Tuesday. Like the law of probabilities, my analysis must be based on experience. In this series, 2 comparable shots have required 3 weeks, 2 weeks, and 1 week respectively after they were ready and before there was acceptable weather. So your chances are something between 1 in 7 and 1 in 21, perhaps 1 in 14. Possibly conditioning these odds, however, is the fact that statistically wind directions are more favorable on more days at this season than they were last February.

THE DEPARTMENT OF DEFENSE IN ATOMIC TESTS

BY MAJ. GEN. LELAND S. STRANATHAN, *USAF, Commanding General, Field Command, Armed Forces Special Weapons Project, Sandia Base, N. Mex.*

The remarks of Dr. Graves and Mr. Goodwin have given us an insight into the closeness of the relationships which exist between interested parties here at the Nevada Test Site. Team work is the order of the day and this is fortunate since the complexity of the operations involved in just one shot is enough to occupy the planners for many months ahead.

Of necessity much of the energy and resources of our Nation have gone into the application of atomic energy to military purposes during the short period that this new source of energy has been available for use.

Major emphasis has therefore been placed upon the development and production of atomic weapons and to the building and maintenance of a capability for their effective use if required to preserve our freedom. The first of these tasks—development and production—is the responsibility of the AEC. The second—capability for effective use—is the responsibility of the DOD and the Armed Services. Our interests in tests therefore are exactly the same. It is only that we have divided the task.

The purpose of my remarks is to explain why and how the Department of Defense participates in the test programs.

There are three primary objectives in military participation. First, the assurance of compatibility of AEC developments with DOD weapons systems. Second, the acquisition of effects information for military use, both offensive and defensive. Third, the reduction of total costs to the Government by preventing duplication of effort.

As a secondary objective, test detonations are used to train troops to check our weapons delivery systems and to try to discover and correct weaknesses in our techniques, tactics, and equipment. "Desert Rock" operations and participation by some tactical aircraft are examples of programs for this purpose.

You have heard, or will hear, the term "Joint Test Organization" connected with atomic tests. The term refers to that group of people who actually conduct the tests. Its membership is drawn from many sources. The field organization and scientific laboratories of the AEC, Federal Civil Defense Administration, Department of Commerce, Department of Health, Education, and Welfare, Army, Navy, Air Force, Marine Corps, and Armed Forces Special Weapons Project all are represented in the Joint Test Organization.

This is no haphazard grouping. Each draws upon the skills and know-how of the others. Each agency represented has a vital interest in the active or passive defense of the Nation.

In such an organization of over 1,000 people, hundreds of problems arise, thousands of questions are posed. To prevent utter confusion, one man must be the boss. In this test series that man is Mr. James E. Reeves of the Santa Fe Operations Office, AEC. Mr. Reeves is assisted by Dr. J. C. Clark, Test Director, Dr. Alvin C. Graves, Scientific Advisor, Mr. Harold Goodwin, FCDA, and Col. H. E. Parsons, Military Director of Weapons Effects Tests.

Colonel Parsons is Mr. Reeves' Deputy for Military Operations. As such he acts for the Chief, Armed Forces Special Weapons Project, who is responsible for coordination of all military participation in the test series.

The military interest in these tests is thorough, precise, and comprehensive. Some of it will be obvious to you. You will see items of equipment exposed. You will observe aircraft and tanks maneuver. What you will not see are the approximately 500 military scientific personnel from 20 different Armed Forces technical laboratories. You will not see the electronic computers, the thousands of graphs, the millions of words all used to prepare for these tests.

The formal preparation of the military projects in this operation began in August 1953. At that time the preliminary planning phase began. During the following 13 months the developing plans were integrated within the DOD. Similar projects proposed by different services were merged. Some projects were rejected. Among reasons for rejection were: "This information can be derived from known results," "This can be done more cheaply (or better) in the laboratory." Conferences were held weekly and semiweekly. Conflicts were resolved. Improved instruments were devised. Concurrences were obtained from the AEC and the DOD.

Then the entire military program was sent to Field Command, AFSWP, for implementation. The Director, Weapons Effects Tests, and his staff began the military preoperational phase. Blueprints for necessary construction were prepared. Exact ground locations for each instrument were plotted. Requirements for electrical power, timing signals, high-speed photography, and soil stabilization were consolidated, and changes to plans continued.

The Military Scientific Group then moved from Albuquerque to Camp Mercury and physical labor was added to mental effort. Finally on February 18 the first device was fired and the operational phase was underway.

To date, 12 nuclear and 1 non-nuclear tests have been completed in this series. After 2 more, public interest in Operation Teapot will wane. But for the military participants, this means only "now we can get down to work."

The postoperational phase may last as long as 12 to 18 months. During this period, miles of motion picture film will be studied, measured, and discussed; oscilloscope photos will be calibrated; radiochemists will run thousands of quantitative and qualitative analyses; telemetered data from films and traces will be interpreted; and another flood of machine computations, graphs, and words will spell out what happened and what significance it has.

Most of you will not see the hundreds of technical reports on the results obtained. They will go only to those who must have these data in order to discharge their duties effectively. All reports having civil defense implications will be sent to Governor Peterson and his staff.

Much of this information will eventually be utilized by FCDA in its plans and also published in unclassified form. Those having purely military value will be sent to the military agencies charged with responsibility for making our Armed Forces strong in the use of, and defense against, atomic warfare. We hope that we may never be forced to use atomic weapons. However, we would be guilty of criminal negligence if we failed to acquire essential knowledge for their effective use.

Within the Department of Defense, the Armed Forces Special Weapons Project is responsible for coordinating the participation of the military services in the conduct of military effects tests in conjunction with the AEC test programs. Accomplishment of the objective of the military programs in tests can be generally divided into two steps.

The first is to investigate fully the physical phenomena associated with atomic weapons explosions.

This is accomplished by measurement of blast and shock, thermal radiation and nuclear radiation under various conditions of detonation. The second is to determine the effects of atomic weapons on personnel and material objects by utilizing information obtained from the physical phenomena. Representative experiments in this second category involve:

1. The determination of the effects of atomic weapons on military field equipment such as tanks, trucks, artillery, and upon military personnel.

2. The determination of the relative effectiveness of various types of protective shelter.

3. The effects on aboveground and underground structures of military interest.

4. The effects on aircraft and naval vessels.

Much of the information gained can be applied equally to the civilian and the military situations. All information in this category is furnished the FCDA or other appropriate agencies.

The projects involved in these atomic tests utilize models of structures, parts of structures, full-scale buildings, numerous pieces of equipment and instruments. The information gained from tests of specific structures or

items of equipment is then related to other structures and equipment of the same type. The damage caused by a specific yield is related to other yields.

In this manner, we are able to predict the reaction of a wide variety of structures or equipment to a broad spectrum of weapon yields. To do this, we utilize information gathered in a relatively few tests.

In addition to conducting military effects tests, the DOD performs many other functions in test operations. Examples include the Navy's logistic and security functions on the test series in the Pacific; the Air Force Special Weapons Center's operation of an air control center for all aircraft participating in continental test series, furnishing aircraft and crews for bomb-dropping, aerial scientific measurements, and air logistic support; the Army's Chemical Corps radiological test monitoring within the Test Site; erection of certain test structures by the Army's Corps of Engineers; special meteorological observations made by the Army Signal Corps; and extensive activities of the U. S. Air Force Weather Service.

These tests cost money—a lot of it. They also have a high cost in terms of time and effort of thousands of highly-trained support personnel and keen-minded scientists both in and out of uniform.

Questions in the minds of many people appear to be, must we continue to develop and test atomic weapons? The answer is clearly Yes. Haven't we already obtained all the information we need? To this question the answer is No. You have all heard the old phrase: The more you know, the more you know that you don't know. I feel we have only scratched the surface. Adolph Hitler froze aircraft design in his Luftwaffe, and lost it. The examples of failure to continue to seek improvement are endless. We dare not take the chance.

THE ATOMIC ENERGY COMMISSION AND CONTINENTAL TESTS

BY DR. JOHN VON NEUMANN,
Member, U. S. Atomic Energy Commission

I know that all of you have steadily in mind the reasons why these nuclear tests are being held. They are tests which contribute to the defense of the United States and the free world. They spring from the realization that no free nation dare fail to keep its protective defenses strong and alert in the world situation of today.

The only safe alternative to maintaining a strong defensive posture is disarmament of the sort which the United States has steadily proposed to the world through the United Nations, starting in 1946. Such proposals have failed because of the intransigence of one nation. Nevertheless we continue to put them forward and to press for them in the Special Commission of the United Nations which is even now meeting in London.

Until there is acceptance of a workable, safeguarded plan for disarmament, there is no alternative but for us to keep our defenses in being and up to date. That is the main reason for the tests being carried on this spring, one of which you are here to witness. The determination of the United States to seek worldwide, effective disarmament has been underlined again by the President's recent appointment of Mr. Stassen as a Special Assistant for Disarmament Affairs with cabinet rank so that the matter may be continually and vigorously furthered.

As the world situation stands today, no free nation can neglect its defenses; all must be on the alert. Our country must maintain military strength and vigor substantial enough to repel aggression, when and if it occurs. In the words of Chairman Strauss, spoken last week to the Joint Congressional Committee on Atomic Energy of the Congress: "The weapons we test are essential, not only to our own security and that of the free world; they have been and may well continue to be a deterrent to devastating war."

But there is more to our armaments than our arsenal. There is the problem of organizing and operating a going civil defense system. For to maintain a strong military posture, we need to maintain the capacity to mobilize swiftly the civilian effort vital to all lines of military support; and to organize our people to protect themselves and their families in case of assault.

My feelings about civil defense can be stated shortly and simply. I believe that next to direct support of Government activities designed to defend against enemy attack, we have no greater responsibility than to

marshal all possible effort to meet the problems of civilian protection and recovery from injury if attack should come upon us.

You are going to hear much more about civil defense from Governor Peterson and his staff, whose responsibilities and capabilities in this field give them authority and competence to speak. All of us in the Atomic Energy Commission are gratified that this organization has been able to help the Federal Civil Defense Administration carry on the wide variety of civil effects tests that have been conducted in connection with many of the nuclear test detonations. Neither the AEC developmental tests, nor these open-shot programs, would have attained the high degree of success that has characterized them without the fine and varied talents and operational support of the AEC laboratory personnel and of all branches of the Armed Services.

The open shots of course are in the public interest, not only for their aid in civil defense but for their help in bringing to the people of America and the world through public media knowledge of the effects and the behavior of nuclear weapons. These weapons are a fact of the world in which we live and they should be comprehended by the people.

The surest way to bring about such comprehension is through reporting by trained journalists of the printed word, radio, and television of what happens when a weapon is detonated and what its effects may be. For this reason the Atomic Energy Commission welcomes the media representatives here. We will do our utmost to provide you the means of full and accurate reporting.

There have been 12 nuclear detonations and 1 non-nuclear detonation in the current series. The series is the fifth that the Atomic Energy Commission, with the support of the military services, has conducted at the Nevada Test Site.

As you all undoubtedly know, in the testing program at the Nevada Test Site, only relatively small energies are released in the detonations, in contrast with the much larger yields of fission and hydrogen weapons tested in the Pacific Proving Grounds in the Marshall Islands. In Nevada, we do not test the nuclear devices of large yields.

Though the yields are relatively small in the tests here, and any hazard correspondingly small, the AEC has an overriding concern for safety of the workers onsite and the public offsite. We have given our test organization very explicit instructions detailed in an operational guide to make certain that very rigid criteria in the interest of public safety are met before any one of the detonations is set off. As you have read in the newspapers and heard on the radio and TV, this has resulted in rescheduling several of the smaller shots for days when it was hoped that larger ones might have been detonated. However, the net effect, I am told by the test organization, has not materially lengthened the time for completing the test series which should be terminated in early May.

If there is any rescheduling of the detonation of the open shot, you may be assured that it is done to prevent any hazardous occurrence of blast or radiation effect, even to a minor degree, off the test site.

We all hope that the schedule will be followed and the detonation will occur on April 26. I am certain that if conditions are right you will see it on that day, but if conditions are not right under the Commission's operational guide, it will not be fired. In that case, I hope you will all take it in stride. I hope you will be tolerant of the men in the test organization who bear the heavy responsibility for shooting or not shooting. If the shot has to be rescheduled, everyone will be doing their best to fill in your time profitably until the detonation can take place under the operational guide.

As I have mentioned earlier, the relationship between the weapons testing program of the Atomic Energy Commission and the ability of the military forces of the Nation to resist aggression is clear-cut and is obvious to a group such as this.

However, there has been a good deal of more or less articulate concern about continued nuclear testing by this country. Let me restate the commanding reasons that dictate United States testing activities.

In a world where the free peoples have no atomic monopoly the United States must keep its nuclear strength at a peak level. Our tests are designed to further development of nuclear weapons. The development of nuclear weapons involves four principal lines of work, primary experimental research, theoretical investigations and calculations, component development experimentations, and full-scale nuclear detonations. If any one of these lines should fall behind, the rate of weapons progress would be slowed. If any one were abandoned, the whole program would soon be compromised. As far as the rate of testing is concerned, one important factor on which it must depend is the rate of generation of new ideas.

Full-scale nuclear tests serve many developmental purposes. These are typical: Tests are needed to assure the adequacy of a weapon before it is placed in the national stockpile; to provide a firm basis for undertaking the extensive engineering and fabrication efforts necessary to develop an initial model to a state suitable for stockpiling; to demonstrate the adequacy (or inadequacy and limitations) of current theoretical approaches; to explore phenomena which can seriously affect the efficiency and performance of weapons but which do not yield to theoretical solution; to gain time in very urgent development programs by short-cutting protracted laboratory calculational and experimental work; and to provide as a byproduct basic scientific information.

That is a fairly long "why" it is necessary to conduct tests of nuclear weapons. As to why such weapons are tested at the Nevada Test Site rather than in the Pacific, there is a simple answer. The testing in this outdoor laboratory so close to the Los Alamos and Livermore Scientific

Laboratories can take place relatively quickly, with minimum lost time. To conduct tests in the Pacific requires a task force of thousands of persons and months of planning and preparation. We need both test sites, and if we are to maintain preeminence in atomic strength we must continue to utilize both sites.

May I speak a word about the fallout of radioactive particles from the tests here. There has been some public confusion here and abroad between this and the fallout from larger explosions at the Pacific Proving Ground. In this respect the following circumstances should be noted:

The yields of the atomic devices fired at the Nevada Site are much smaller than those of the thermonuclear weapons tested in the Pacific. The smallest one tested in Nevada is several thousand times smaller than the typical weapon fired in the Pacific. The testing of those high-yield objects is restricted to the remote Pacific site. Many of the Nevada tests are for tactical weapons, designed for use against comparatively small targets.

The Commission knows from its nationwide monitoring that the fallout from the Nevada tests, even in communities near the site, has never approached a level that is a health hazard. The fallout in most of our cities has amounted only to a small fraction of nature's normal background radiation that is present in soil, water, and air. As far as we know, no civilian onsite or offsite has ever been injured due to the effects of these tests.

We can assure the American people that we are aware of our responsibility to prevent injury to the people of any community or city. Our strict safeguards are designed to achieve this.

I understand that you will hear more about the monitoring system which extends widely and thoroughly in the United States.

As this Nation goes forward with strengthening the nuclear bulwarks of the free world against aggression, it has launched upon a course of encouraging and helping the development of the use of the atom for man's peaceful purposes in all nations of the world. Domestically, we are pushing out into new territory in the development of the atomic reactor as a source of heat for generating electric power.

Five prototypes will be built over the next few years by the Atomic Energy Commission. One is already underway partly financed from private utility funds; one to be built without Government aid has been applied for. There were four applications to take part in further ventures by private and public power concerns under the power reactor demonstration program. The total envisaged under this proposed program, which will only be the first step, and ought to be fully operative before 1960, will be about 750,000 electrical kilowatts, nearly 1 percent of the Nation's present total output.

The method of getting access to nuclear knowledge by private and educational interests has been simplified, as announced on Wednesday of this week. We are engaged in a large publishing program to get into available form the documents which convey this knowledge and which have been downgraded or have been declassified recently or in past years.

The use of the radioisotopes for medicine, for industry, and for agriculture steadily expands.

Our knowledge of the technical data in the field of beneficial uses—so far as it can be declassified and made available—will be put before the engineering and scientific world at a UN conference in Geneva next August. We are erecting at Geneva an operating research reactor for demonstrations at this conference.

For students from other lands, we have started a reactor training school at the Argonne Laboratory and will in a few days open at Oak Ridge a training course in handling isotopes. We are pressing forward with negotiations for bilateral agreements for exchange of knowledge with individual nations and for a multilateral agreement for an international atomic energy agency, as proposed in President Eisenhower's great address to the General Assembly of the UN on December 8, 1953, and authorized by the Atomic Energy Act of 1954.

We have offered libraries of our unclassified atomic knowledge to the nations of the world, and several have already been presented.

The President has authorized the allocation of 100 kilograms of enriched uranium as fuel for research reactors in other nations—a resource without which they cannot go forward in training in nuclear research and use. We have agreed in principle to make available heavy water to India and Italy.

Other enterprises are also afoot working toward the development of beneficial uses of atomic energy. Our record is one of cooperation and promotion of the peaceful uses of atomic energy. In the words of the President, we strive "to find the way by which the miraculous inventiveness of man shall not be dedicated to his death but consecrated to his life."

RADIOLOGICAL SAFETY AND NEVADA TESTS

BY DR. GORDON M. DUNNING, *Division of Biology and Medicine, Atomic Energy Commission*

The detonation of a nuclear device inherently must be accompanied by the release of large quantities of energy that appear in the form of blast waves, and radiations, both thermal and nuclear. Since there are no known ways of obtaining certain information without actually testing the nuclear devices, the problem then becomes one of reducing to a minimum any possible hazard to the public that may result from these three principal effects.

As a first step in meeting safety criteria the Atomic Energy Commission detonates only the small nuclear devices at a site in Nevada that was selected after extensive studies were made of suitable areas in the United States. This site is closed to the public for reasons of general safety as well as security. Aerial and surface surveys are made prior to each shot to ensure that no one has wandered into the site where the effects of the nuclear detonation might be hazardous.

The time of detonation is publicly announced before each shot. In addition if there seems to be a possibility that the blast may be greater than usual in a particular community the people are advised to open the windows to help equalize the air pressure. No one off the Test Site has been injured by the blast either directly or indirectly. In fact, the detonation of over 40 atomic explosions at the Nevada Test Site has caused property damage amounting to only $48,000 of allowed claims.

The thermal radiation, at distances away from the Test Site, is insignificant except for the flash of light. The public is advised not to look directly at the fireball except through very dark glasses and is cautioned never to use binoculars. To assist the passing motorists, roadblocks are established shortly before a detonation to inform them of the expected flash of light. Likewise a circle of about 65 miles is established around the Nevada Test Site, in which aircraft travel is restricted from 30 minutes before the planned time of detonation until 30 minutes afterward.

To date there have been no known cases of serious eye damage to the general public off the Test Site or to civilians onsite. Four members of the Armed Services—all of them participants in the test operations—did receive eye injuries onsite during the 1952 and 1953 test series in Nevada. The Department of Defense advised the Atomic Energy Commission that three of the military personnel received only minor eye injuries which com-

pletely healed, and the fourth suffered serious eye injury through his own negligence in disregarding safety instructions.

Of the three possible effects of a nuclear detonation the one that has received the greatest attention has been radioactive fallout. It would not be appropriate here for an extensive or technical description of this phenomenon but there are a few basic facts that should be made clear.

At the time of a nuclear detonation radioactive isotopes are produced and swept into the air. If the detonation is high above the ground the radioactive particles formed will be small and will descend only very slowly to the earth's surface. In the meantime they are greatly diluted by being spread over large areas, even around the world, and at the same time they will lose a great proportion of their activity by decay. For example, the level of radioactivity at one hour is about 135 times less than at one minute.

If the detonation is near the surface of the earth so that the fireball touches the ground, great amounts of the larger-sized particles are swept into the air and will descend more rapidly to the earth in areas near the site of detonation. They, too, will lose their activity with equal rapidity as do the smaller particles, and eventually the amount of radiation they emit will be indistinguishable from the normal background radiation.

It is important that we realize that the phenomenon of radiation did not first appear with the advent of the atomic bomb. Probably since man existed he has been bombarded with radiation from naturally occurring substances on the earth and from cosmic rays coming from space. The biological effects of radiation from fallout are no different than those from natural background sources. We are not confronted with some new and strange phenomenon but rather we are dealing only with additional amounts of the same general kinds of radiation. What needs to be evaluated is how much more radiation has been added due to fallout and what does this mean in layman's terms of biological effects.

We must use some unit to measure the amount of radiation, and we call it a roentgen. The definition of a roentgen is rather technical and does not indicate directly the biological effects of radiation, so that probably it would be more advantageous to express the amount of radiation in terms of the number of roentgens that one may receive from commonly known sources. For example a normal chest X-ray will deliver about 0.1 roentgen, and in the course of one's normal lifetime about 10 roentgens will be received from natural background causes.

Through the extensive use of X-rays in the past as well as more recent data gleaned from greatly diversified experiments with atomic energy and radioisotopes, we have come a long way in our understanding of the biological effects of radiation. Certainly not all of the answers are known today but we are in a position to make some fairly reliable estimates for some of these effects. They will be considered under two categories: First, the

effects on the individual himself and second, the inheritance of the result of any radiation damage to the germ cell. These are known as somatic and genetic effects.

Somatic Effects

About 25 roentgens are required to produce any detectable biological damage. This injury is in the form of some minor blood changes that are neither serious nor permanent. At about 100 roentgens, temporary radiation sickness might be expected in a small percentage of the individuals and with 250 to 300 roentgens delivered in a short time there probably would be some deaths. If the time of delivery of any given radiation dose is extended, then appreciably greater amounts would be required to produce the same effects. This is due to the simple fact of body repair of some of the damage.

How do these quantities compare with the actual radiation doses received by the people in the United States resulting from fallout? Since we are concerned with each and every individual it would not be fair to quote averages when evaluating these somatic effects. The highest known estimated radiation dose from fallout from all nuclear tests to any locality in the United States where anyone was living (about 15 people) has been about eight roentgens—and I hasten to add that this amount was delivered over many days and weeks. Because of the effect of this long time of delivery, the radiation dose was probably at least 10 times less than the amount required to produce even minor and transitory blood changes and so far below the amount necessary to produce temporary radiation sickness that it is difficult to estimate. The highest radiation dose to any community to date for the current series is 1.5 roentgens. There was another location where the accumulated total dose was estimated to be about 3.0 roentgens. There are or were some transient railroad workers living there. It is not known how long they will work or live at this location, but at the most they will accumulate only about 3.0 roentgens. This is within the operational guide of 3.9 roentgens.

It is not unusual for the amount of fallout, even at some distance from the test site, to be sufficient to register on such sensitive instruments as a Geiger counter. There have been occasions during the current series when this has occurred, for example, at Denver, Chicago, and Niagara Falls, and in some instances have been the cause of concern on the part of those individuals reporting their findings to the press. These misgivings might be understandable unless the readings are properly interpreted. What is of concern here is not the transient rise in radiation levels but rather the total radiation exposure that one might receive. For example, it has been reported this spring that a counter temporarily registered *40* times above the normal background level, yet the total additional radiation dose was only a few *thousandths* of a roentgen—an insignificant amount in terms of health.

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The question may be raised as to the possible hazards from inhalation or ingestion of the radioactive materials. A vast amount of data has been collected and analyzed dealing with air and water concentrations of fallout material and the preponderance of evidence supports the conclusion that the internal hazard is secondary to the external radiation doses. For example, the highest concentration of fallout found in the air anywhere outside the test site was such that the radiation dose delivered to the lungs would have been less than the dose that one receives in a month by breathing normal air containing naturally-occurring radioactive substances. The highest concentration in water, found in an irrigation ditch, was 60 times *less* than the maximum permissible concentration (a value which itself contains a large safety factor), even if the water had been stored up and made the sole source of supply for a lifetime.

Genetic Effects

The evaluation of the genetic effects is made quite difficult due to the uncertainties in our fundamental knowledge in this field. There is not unanimity of opinion among recognized geneticists but certain facts have become widely accepted. It would be inappropriate here to attempt a discourse on genetics or even attempt a listing of the generally accepted facts. However, it is essential that we indicate a few.

1. Radiation can cause changes in the germ cells. These are called mutations and they are usually deleterious to the offspring.
2. Radiation is only one cause for mutations (and probably not the major one), nor would radiations from fallout produce any types of mutations not already known and occurring naturally.
3. The number of mutations undoubtedly depends upon the total amount of radiation received without regard to the length of time of delivery.

We are not dealing with some new and strange phenomenon when we evaluate the effects of the radiation from fallout but rather we ask ourselves how much more radiation has fallout contributed to that normally received every day from natural causes. Because of the very nature of inheritance the appraisal of genetic effects lies not with the individual, but with large populations. What then has been the average exposure to the people of the United States from fallout?

Through the intensive efforts of the Atomic Energy Commission a countrywide monitoring program of fallout provides an estimate to this question. The average exposure to the people of the United States to date from all tests, American, British, and Russian, has been about $\frac{1}{10}$ of a roentgen (incidentally, this is about the equivalent of the dose delivered to the chest from an X-ray). In other words, this is about 100 times less than the amount of radiation that people receive over a lifetime from

natural causes. Since rediation accounts for only a part of the natural rate of mutations, this means that the added contribution to the mutation rate from all fallout to date has been considerably less than 1 percent.

It is sometimes argued that doubling the natural mutation rate would produce a large enough number of new mutations to be detectable in a population. Estimates of the total radiation dose necessary to double the natural mutation rate range from 30 to 80 roentgens. These values are 300 to 800 times larger than the total dose from all fallout to date.

What if we continue our testing program every year? Once more we may compare the radiation doses from these anticipated fallouts to those received from natural causes. If we take the series of tests that produced the highest amount of fallout in the United States and assume that these would be repeated every year during the lifetime of an individual, the total dose received on an average by the people in the United States would be about $\frac{1}{10}$ that from natural background causes. Since there are natural factors other than radiation that cause mutations, the possible increase in the rate of mutations from this amount of yearly fallout would be too small to be detected.

There are other aspects that might be discussed such as the radioactive strontium and iodine found in the fallout material, but analysis of the findings to date clearly indicates that the radioisotopes have not concentrated in hazardous amounts anywhere. What is further reassuring is to know that our extensive monitoring programs keep a day-by-day tabulation of fallout so that there can be no significant trend without our knowing it well in advance of any possible levels of concern.

This system of forewarning is equally true for the more immediate fallout around the test site. More than 100 personnel from the test organization devote their full time during testing periods to the task of directly protecting the public. Right now, there are in operation around the Nevada test site 12 fixed monitoring stations, 6 mobile teams, 26 automatic radiation recording instruments, as well as a variety of other radiological instruments, plus 29 telemetering stations. These telemetering stations are quite unique in that one may place a telephone call in the normal manner to any 1 of the 29 communities and receive back signals that are translated into radiation readings in a matter of seconds.

All of the detonations at the Nevada test site to date have caused eye injury to 4 participating military personnel, 3 temporarily and 1 serious, and a radiation exposure of 39 roentgens to 1 guard who has shown no detectable injury. There have been no injuries to personnel offsite.

The only recognized radiation injury was in 1952 and 1953 when fallout occurred on some horses and cattle grazing between 10 to 20 miles from the site of detonation. Claims amounting to $5,900 were paid for these animals. As was indicated earlier, there were allowed claims, due to blast damage,

of $48,000. This makes a total of $53,900 paid for damages and injury for the 43 nuclear detonations. This is about $1,300 a shot—an insignificant sum compared to the value of the testing program to the United States.

We all recognize the absolute essentiality of our stockpile of nuclear weapons in the defense of our country. These do not come directly from the drawing board; they come by way of a series of long, hard steps of development, with the field testing as a critical link in the chain. We could not have reached our position today in nuclear weapons nor can we maintain our advantage without a continuing effort of development and testing. The potential risks involved in detonating thousands of tons of TNT equivalent are real; it would be foolhardy to pretend otherwise. The problem then becomes one of reducing to a minimum those potential risks. The facts given above attest to the success of conducting nuclear tests in Nevada without significant hazards to the public.

THE FALLOUT PROBLEM IN CIVIL DEFENSE PLANNING

BY DR. JOHN BUGHER, *Former Director, Division of Biology and Medicine, Atomic Energy Commission*

In discussing the civil defense aspects of fallout, I naturally base these remarks on those made the other day to you by Dr. Dunning, who reviewed the broad problem of health and safety with respect to radioactive fallout from nuclear weapons. If we are concerned with civil defense matters primarily, I think we will then omit, as far as this present discussion is concerned, what might be called the long-term effects, the long-range problems. I will confine my remarks then to the immediate emergency situation of atomic attack, with various levels of energy yields, and will not go into the more protracted problems associated with the persistence of radioactive material in the environment.

In recent months a great amount of technical and factual material has been made available in this general field, and I presume that all of you have had occasion to read the various statements that have been issued. It is upon the basis of this system of well-determined factual knowledge that we have to think of a civil-defense problem.

In connection with this problem of radioactive fallout, one has to realize that part of the mechanism here lies in the bomb itself, and part is dependent upon the particular situation and the circumstances of the explosion.

When a weapon which involves fission of heavy elements is detonated, there is the production of a vast number of highly radioactive and unstable elements; practically the entire central section of the periodic table results. There is an enormous range of elements, including a large proportion of elements that normally do not exist on earth at all in the state in which they are found at the moment of detonation. First of all, we have the production of a mass of nuclear material which itself is highly radioactive; element changing to element, at varying rates of speed, with the emission of gamma radiation, which is very much like high-energy X-ray, or with the emission of electrons, which we call beta radiation. There are other components, but for our purposes I'm going to confine myself to those two forms of radiation. When dealing with the immediate radiation of the bomb, the neutron flux comes into the picture. From the standpoint of our discussion, we think particularly of gamma and beta radiation, the first having a great penetrating quality, the second having a very short range in air or in material substance.

There is the release, then, of a mass of radioactive material of tremendous activity—I think one can hardly imagine adequately what the degree of

activity is. As an analogy, roughly speaking, what we call a mega-curie of radioactivity in a gamma sense, is that which would be released by a ton of radium. Now, a ton of radium is many hundreds of times more than all of the radium which has ever been separated and brought into human control. The actual amount of radium which we have under human control on the earth is only a few pounds. But a mega-curie of activity is approximate then to a ton of radium.

In even such a device as we hope you will see tomorrow, in the moment following the detonation, while the fireball is still relatively young and the illumination is extremely intense, the activity will be equivalent to several million tons of radium.

The next thing that is important about this is that some of this horde of elements created in this instant disintegrate and change extremely rapidly, living only a very small fraction of a second. Others take many seconds; others minutes; still others hours, days, weeks, and in some cases a few have half-lives—that is, they are gone, disintegrate by 50 percent—in terms of years, 20 years in the case of Strontium 90, which is a very important component; 30 years in the case of one of the isotopes of cesium. That is about the end of the story as far as the important ones are concerned.

So time then begins to play an important part here. From the moment of detonation, the tremendous activity which is established decreases at a rate which itself is dependent upon the time since detonation. This material, at first very hot and in vapor form, begins to condense as the fireball expands and grows cooler.

The fireball, though still at many thousands of degrees, is really a very cool thing compared to the starting temperature. As this fireball expands and cools and rises through the atmosphere, the material begins to condense. It will condense, depending on the vaporization temperatures of the various elements. Some of them are solid at very high temperatures—others remain gaseous throughout. There can also be an admixture within the fireball of a considerable amount of extraneous material, solid material, from the tower itself, which naturally in this instant vaporizes and vanishes—also the instrumentation in the cab vanishes—all coaxial cables and the various conduits and the special equipment all go to vapor and are in the fireball.

In addition to all of this hardware that you see going up in the sky from a tower shot there may be a large amount of earth which is sucked up into the air around the tower. It also enters the fireball. The amount of such earth is dependent on the height of the burst above the surface. With air bursts high above the ground, one expects nothing in the way of such additional material. With a detonation at the surface of the ground, there will be a large amount, a huge tonnage in fact, of dirt taken into the fireball. This material tends to accelerate the condensation of fireball radioactive

material. And we find that upon such particles, which tend to be somewhat coarse, there may be very marked deposition of radioactive elements. This forms a very important component in the fallout mechanism. Such particles, being coarse, fall through the atmosphere much faster than those which are very small and below the level of microscopic vision.

The factors which determine where the material comes to rest are clearly those, first of all, associated with the height of the cloud, the starting point, in other words, for such particles. The second system of factors has to do with the structure of the atmosphere; that is, the winds, their direction and velocity, at various levels.

The height of the cloud is dependent on the size of the explosion and also upon meteorological factors. The size of explosion is an important determining factor in the height to which the cloud rises and the point from which the particulate material must fall.

Also, as the cloud hits the stable layer which we call the tropopause, it tends to flatten out. If the shot tomorrow goes to a reasonably good yield, you should see the top of the cloud actually make contact with the tropopause spreading out at that point. Even in the thermonuclear weapons this phenomenon of contact of the cloud against the tropopause is a very important factor which, in conjunction with the turbulence locally, results in a cloud that will extend over many miles.

I remember that the cloud from the November 1st shot, the first thermonuclear shot in 1952, had a fantastic rate of spread through the sky, so that in the course of a few minutes the diameter was approximately 100 miles. In such a case the fallout material then begins from a very broadly spreading cloud and not from a single center.

The time taken for the fallout is determined by the height from which the material starts, the size and density of the particles, and the density of the atmosphere. The place at which the material comes to earth will be determined partly by the time that the material takes in falling, and the speed of the wind which acts on the material during that time. From all of these factors, it should be possible to predict reasonably well where the material is going to come to earth.

The material which exists in the radioactive cloud is very finely divided particles, and these fall very slowly. This is the material that we measure over the United States and world and can show oftentimes its passing around the world two or three times. It takes a long time for some of this very finely divided material actually to get down to earth. Radioactive decay taking place during that time is of no consequence to anybody, because any radioactive decay in the stratosphere has no importance as far as life on the surface is concerned.

As we come down to lower yield weapons, we find that the whole structure that has been described gets smaller. What we have here at Nevada is not

inherently different from the fallout picture of the large-scale weapon, except that it is quantitatively different. It is a miniature representation of it. The contours, which you will see as they are developed, are oftentimes similar. The intensities scale down though, and the areas are scaled down. So that where we talk perhaps of hundreds and thousands of square miles for a thermonuclear weapon at high yield, we deal in Nevada with square miles of heavy contamination. But what is heavy contamination in Nevada is contamination that is measured in tens of roentgens total dose, whereas from a large thermonuclear weapon in a similar situation, the total dose may be in hundreds and thousands of roentgens, so that the scale of things is completely different, but the pattern has many points of similarity.

Here then is a system, a mechanism, which is predictable. It has characteristics which are dependent on circumstances of detonation, and upon existing environmental factors which pertain at the time of detonation.

When we talk about what may be done by the civil defense organization, we have to separate those things which are of overriding importance and those things which are important but only secondarily so. The overriding matters are, first, the general external gamma exposure from the fallout material, either in the air or on the ground; the second overriding consideration is the combined beta and gamma radiation of skin surfaces, due to adhesion of particles of material in considerable amount. Compared to these problems, it appears that the hazards of inhalation and ingestion—that is, breathing the material into the lungs and swallowing the material into the gastrointestinal tract—are relatively minor. In fact, we prefer to ignore them in this civil defense situation. If we take care of a situation such that the whole body gamma radiation is acceptable and the skin contamination is acceptable we are not going to produce too many illnesses from these factors and the other two things, while important, in this scale will take care of themselves.

The factors that are important in the civil defense approach to this problem are, first of all, the matter of time. As I said, with the progressive decay of the radioactive material, which is very rapid in the first minutes and in the first hours, time is one of the most important factors that we have. If the contact of people with material can be delayed by any factor of time whatever, it is a substantial advantage. The closer to the explosion time we are concerned with, the more important even a few minutes of delay will become. Time is an extremely important factor in talking about protection of people.

Secondly, is distance from the radioactive material. If you can't get away from it entirely, get as far away as you can. While some of these considerations of inverse square law do not wholly obtain in the case of a

surface widely contaminated, nonetheless, the principle is used to advantage in removing oneself as far as possible from the source of radiation.

The third thing, shielding, is interposing between people and the source of radiation as much inert material as possible, and anything is better than nothing. The heavier the material, the better. As we mentioned yesterday, earth is usually the cheapest and the most available material. Concrete, iron, lead—all of those things are of great advantage.

The fourth factor of containing the material, to get it together in a single spot, and clear away areas, is oftentimes to be a point of advantage. If we put these things together, what do we have from a practical civil defense standpoint?

We see at once that we can do a lot. We have had to express the hazards of this situation in terms of a man, who will do nothing but just sit and wait for something to be done for him. In that case we can say what the percentage of fatality is going to be. We can draw curves within which everyone will die, more curves within which half the people will die, and still others farther out in which a given percentage will die if one assumes that this man is not going to move a hand to help himself. If, however, there is adequate training, and previous preparation, the mortality from the fallout situation may be tremendously decreased.

The civil defense concern then begins long before there is an attack. It begins in planning and recognizing that one can predict a fallout pattern from the circumstances that exist at any moment. While we oftentimes have fun about the predictions of the weather people, because they may predict an area behavior where we are concerned in our own private lives with just what happens around us, we also have to realize that within the last decade enormous advances in knowledge of meteorology have taken place.

That is the reason why these tests are possible. If it were not for the ability of the meteorologists to accumulate data from farflung observation points, to bring it together within a short time, to analyze it, to predict what will happen at a given hour tomorrow—if it were not for that, these tests could not be conducted at all. Let us recognize that we have within our own capabilities the wherewithal to maintain a running prediction system for any target area, provided we have the adequate facilities for meteorological observations, particularly at high levels, up to 150,000 feet, especially in these large bomb situations, and it becomes possible to predict for any hour some sort of an approximation of a fallout area. It may not be exact, but think of the difference that it makes to the civil defense organization of a city to know that if an attack occurs at six o'clock tomorrow morning, the fallout pattern will extend in general to the Northeast, and will have certain characteristics. If an evacuation is to be carried out, the evacuation will be managed with the knowledge that that par-

ticular sector is not going to be an area into which you move people, but rather one *from* which you move them.

So the first civil defense move then is to use to the utmost the existing technology which we do have, to improve it and to rely on an efficient communication of information to maintain a running situation analysis. This begins before there is any attack. It should be a normal function during peacetime, even without any occasion for an alert.

Then if there is a detonation, and if individuals still have to be in the presence of the fallout material, what can they do in turn to help themselves? First of all, we'd like those people who have to remain in a fallout area to have adequate shelter. The shelter, since we are dealing with an area here outside of the blast ring, presumably is chiefly concerned with shielding, and feasibility of inhabitation.

The sheer problem of suddenly translating or transforming a whole population to completely primitive survival conditions is a tremendous one, and radiation is only one factor to be met. In such a shelter situation shielding is certainly important.

There is considerable concern about whether or not the air supply of such a shelter should be provided with elaborate filtering devices. Our experience has been that while we don't like to have people inhale air that has radioactive material falling through it, while there isn't anything that you can say is good about it, it is not the hazard we are going to worry most about in these circumstances.

We learned a year ago from the experience of the Marshall Island people and some of our own task force personnel that the actual amount of inhaled and also swallowed material may be quite small even though the surrounding whole radiation hazard is serious. So that simple, reliable, and foolproof—if there is any such mechanism—systems of air filtration might be worthwhile. One has to remember though that if you clean a large volume of air and concentrate all of the material on a small filter, that filter itself then becomes a hazard to anyone who has to handle it. And he has to do so then with some care.

So, while filtration might be desirable, it is not the vital and essential thing that perhaps has been generally thought. This material is heavy enough and falls fast enough that unless there is a strong suction into the intake, not too much of it would actually go into a structure. In fact simple grass roofs were quite effective in shielding the ground underneath from the fallout material of a year ago in the Marshalls.

Then if there is not a shelter, what does one do? Anything that offers protection overhead is a great help. A house of any kind, however thin and flimsy, serves to hold away from the individual the fallout material. He therefore should stay indoors. If he can get into a situation of some shielding, his circumstances become vastly improved. A simple house

offers appreciable shielding protection. A cellar is much better. A simple shelter in a cellar, particularly if concrete or earthfilled, may offer complete protection for high levels of radiation, and so an individual and his family may wait until time has taken care of the high level outside.

If the individual has to be in the fallout material, then as much covering as he has available, particularly over his head, over his shoulders, is all to the good. Any sort of clothing is helpful, because small separations from the skin will be adequate to prevent serious burning of the skin. And most of the material that falls is dry and can be easily shaken out of ordinary clothing.

Oftentimes the advice to take a bath promptly may be somewhat academic, because water would seem to be one of the required elements in a bath, and under the disaster situation which we visualize, water may not be available. But even a dry bath, a thorough shaking of clothing, a brushing of the skin, or wiping of the skin, or to the degree that water is available, washing of the surface of the skin is helpful.

We have found in some situations where individuals have heavily oiled hair that the material tends to stick very tenaciously to such hair and may even resist repeated washing. In such cases one has to do somewhat drastic things and get busy with clippers and scissors and remove what otherwise would be an attractive and decorative shock of hair.

These are simple things—yet they are easy to do and extremely effective.

The general problem is one of anticipating the situation and having a plan which is adequate and does not demand facilities which don't exist or will not exist.

One other thing can be done. We have tried it here in Nevada. I don't think you'll see any evidence of it, but it worked very well. The occasion was the situation succeeding the explosion of one tower. It was desired to build another tower in the same area to get on with another shot some weeks later. The activity was too high to permit people to work in the area unprotected. A bulldozer was used to scrape up the surface—you remember that the fallout material is on the top, the top quarter of an inch actually—to scrape all of this top layer to one side, put it together in a pile, then dig up clean earth, and move that to one side, creating small levies or dikes around the area. Individuals could enter such an area and be partly shielded, remote from the radioactive material, and workmen were able to erect this tower without exceeding the permissible limit of radiation exposure which is adapted to industrial use.

Even where there is a heavily contaminated area through which people must go, cleaning a path may be extremely helpful.

The next thing is speed. One can go through an extremely highly contaminated area if you can move fast enough, for in such an exposure of short time the total exposure may be rather small.

So these are the things that time will further develop into practical means of protection of individuals. Civil defense becomes fundamentally a problem of individuals having training, having reasonable knowledge, and a comparatively simple set of procedures which they can follow under a disaster situation.

Food and water tend to get involved in such outfalls of contaminated material. Under such disaster conditions, it may be rather absurd to debate whether a given volume of water is suitable for drinking or not. If that's all you have, you're going to drink it. The question is can you do anything to it?

You can do a lot of things. The fission products in fallout material are in general only partially soluble, and since material is heavier than water, these small particles tend to settle off. Second, the material is very emphatically absorbed on various earths—clays particularly—and so even a simple procedure such as stirring up a handful of clay in a bucket of water and letting it settle may remove 90 or 95 percent of the total amount of radioactive material that is in the water. You have dirty water from the bacteriological sense, which can be corrected easily by boiling it. It isn't nice water perhaps and still isn't devoid of radioactive material, but it isn't going to kill anybody if it is consumed for a few days.

Similarly with foodstuff. The problems here largely revolve around those foods of considerable surface area to which material tends to adhere tenaciously. It may not be practical to consume leafy vegetables under such circumstances, but ordinary foodstuff usually can be used without any difficulty. Canned material is no problem at all, and even thin wrappings, paper wrappings, carefully taken away, will yield a content which is perfectly usable.

I don't know whether I have covered adequately some of the things that would occur to you, but I think those are at least an indication of the way in which individuals and groups of individuals, facing a situation such as we must contemplate, can do something to protect themselves. It doesn't mean everyone is going to get away without being injured by any means. There is a tremendous difference between a 100-percent fatality and a 1-percent fatality, and any move that will reduce the chaos is certainly all to the good.

Just before I came on I was given a number of questions which had been asked in writing. I'll try to answer them. They are concerned with matters which I have not discussed. Some questions deal with subjects which are more concerned with long-term problems.

Mr. Murrell R. Tripp, mayor of the city of Lubbock, Tex., makes a statement which involves a question: "We have been impressed with the importance the weather has on whether or not the shot takes place. Many

of the citizens in our area are interested in what effect these explosions are having on the weather, rainfall particularly."

It so happens that the Weather Bureau has been doing a special study of this problem for the last 2 years. The question originally arose with respect to tornadoes. You may recall at the time of the last series there were a number of tornadoes in the United States. Although I think we gave sound answers and thoroughly scientific answers to the questions, I had the feeling that probably half the people in the United States believed that the tornadoes were due to the Nevada detonations.

The Weather Bureau has found—and it has been published in the Journal of Science—that not only have the Nevada shots had no effect on the weather, but they have gone back in the records prior to any nuclear detonations and they find that rainfall patterns which we have had in recent years have occurred many times in the past. In fact, there have been periods of greater drought before any bombs were detonated, so that their conclusion has been that there is no demonstrable effect on weather patterns anywhere in the country. As far as tornadoes were concerned, it turned out that there were fewer tornadoes along projectories of atomic clouds than elsewhere, and that there had been actually fewer tornadoes in association with nuclear tests than before and after such tests.

Whether or not in a given locality there would be local weather effects is somewhat a different question. We do presume that locally—right on the test site—one might expect, because of the disturbance of the atmosphere, some effect. Consequently, detonations are not made here in Nevada when there is any prospect or any near prospect of rainfall anywhere in the area. That has worked out very well indeed. There have been no instances of rainfall that I can recall following immediately on a shot here in Nevada. That is based on accuracy of prediction.

If anyone is more interested in this, I would recommend to you a paper by Dr. Machta of the Weather Bureau in the Journal of Science and recent testimony presented to the Joint Committee on Atomic Energy last week by Dr. Wexler, also of the Weather Bureau.

The Honorable Pete T. Saranosa, of the Idaho Legislature, Terreton, Idaho, has a number of questions. "What is the chemistry of atomic fission? What new elements are formed? What rays are given off? And how do they react on people? Is any matter created or destroyed?"

I'll try to answer these in a very brief manner.

The fission of the uranium atom or plutonium atom is not itself chemical. It has to do with the nucleus of the atom—the internal central structure—which is related to the whole atom somewhat in the same manner as the sun is related to the entire solar system. It is the outer part of the atom, the electrons, that give the chemical character, so the nuclear reaction is not fundamentally chemical.

The elements that are formed are extremely numerous, largely because the uranium atom doesn't split equally, nor the same way in a successive uranium atom split, and you get a whole group of several hundred particular radioactive elements which then begin to decay and finally wind up as stable elements of the sort that we do know naturally in our environment. There are a lot of new elements formed which normally do not exist. These new elements decay, changing into things with which we are more familiar. However, plutonium—a new element of the atomic age—has a long half-life of several thousand years, so they don't all distintegrate and become inert so rapidly.

The rays given as I mentioned are largely gamma radiation and beta radiation. In the very early moment of fission, not only are there many gamma energies, but there are also neutron rays, which come off—neutron particles have special activities in themselves, and may activate material with which they come in contact, making it radioactive.

Matter is being destroyed in this reaction. The energy which is released is represented by a decrease in the total amount of material substance. There is a conversion of matter to energy, so that the total mass of all the materials which are formed is slightly less than it was before, and the amount of energy can be computed. If you know the change in mass, or if you know the amount of energy you can compute the amount of mass which has been converted.

He also asks, "Which is most devastating on an area—a bomb dropped and set off at ground level or a device that is exploded above ground level?"

That is something that would be better answered by one of the military people, because it is a technical military question. I will take a pass at it, and you can take it for whatever it is worth. It is not a medical question.

It does seem that the closer a bomb is to something, the more damage it is going to do to that something. On the other hand, if you are thinking of an area in terms of a target and the objective is to throw it out of operation—that is the extent of devastation that is significant and it would not be to any military advantage to destroy more than that—then the maximum in that particular sense is going to be achieved by a balancing of height above the ground with respect to the burst, the area, and the character of the target. There are situations where the bomb damage is maximal from the particular military sense.

In connection with the device exploded aboveground or on the ground, it is a matter of what the intent is. If it is the intent to create the maximum possible radioactive fallout over a large area which is not damaged by blast, and thus deny that area to occupation and effective living, then the device would be detonated at the ground level.

With the very large weapons, such as the multimegaton thermonuclear weapons, the fireball may be so large that it becomes irrelevant as to whether

it is detonated on the ground or above the ground. The fireball would be in contact with the ground anyway.

A question by Mr. N. Gordon Roberts of Elkhorn, Nebraska: "What mutations are observed in, first, plants; second, insects; and third, what is the nature of the changes in mice?"

I think that the question of mutations can be covered in this way—that mutations are always occurring. They are in part due to the radioactivity of the natural environment, which is always with us. They are due to other factors, some of them chemical. The changes are infinite in possibility. Most of them are trifling changes, perhaps in such form in plants as leaf shape, or the number of seeds on a stalk, the character of the flower, or something of that sort. In insects many of these things are simple little changes in color that were not in the race before.

Many of them also are serious things that threaten or in some cases insure the death of that particular mating, or fertilized ovum. It appears that a good many of the mutations are likely to be so-called lethal dominants when they occur in the germ cell; the result of a union of that damaged germ cell with the opposite germ cell may result in a combination that doesn't go any further. In that case you don't have an abnormal individual at all—you simply don't have any individual, and no way of knowing that the individual doesn't exist. In experimental work with mice and insects, you could count these things and take the difference between what you have and what you think you should have and that is a measure of this type of effect.

Then other effects are recessive, may not appear until successive generations, where two people having the same recessive gene may meet. Generally speaking, the mutations that do occur are not advantageous to the individual. Most of them may not be particularly detrimental to him. We all have things of this sort. Every one of us has a good many characteristics, usually carried recessively, that if they appeared, would be to our detriment. We also carry many little dominant things which are decidedly of no advantage but have no particular bearing one way or another. There are all sorts of degrees of significance here; generally speaking, the changes are not favorable. Some of them are. That, of course, is the very basis of plant breeding, the improvement of stalks of plants. However, I don't know whether Dr. Pearse's comment on the similarity of human beings and pigs has any connection here, but as human beings we tend to assume that it would be absolutely impossible to conceive of anything better than man is, as he is. There are others though who might suggest that perhaps even man might be improved on.

Then a question by Mr. Richard Marshall of Norfolk, Va.: "What would be the effect on the city of Norfolk if a bomb were dropped in the water of its harbor as to the lasting effect of radiation in the water which would be spilled on the city?"

Generally, an underwater detonation, even a fairly shallow one, results in the radioactive material being entrapped in the water and largely spilled out locally. The result is likely to be one of enhanced radioactive fallout, due to the washout from the large amount of water carried up by such an explosion. Naturally the depth of water and the direction of wind will be important. But I think that there is no denying the fact that an underwater detonation in any ordinary harbor of even a small bomb would create a very serious radiological situation. It would be a magnified fallout problem.

QUESTION: I am Senator Caudill from Virginia. I should like to know if there are any practical methods by which an average family, say in a more isolated area, could determine whether or not the food or water is contaminated?

DR. BUGHER: Determining the contamination of food or water would take some sort of an instrument such as a Geiger counter or a small ionization chamber. In other words, if one has an instrument adequate to measure the contamination of the food and water, he also has an instrument which will measure much more easily the total environmental contamination, which will be the basis of his further action.

QUESTION: Dr. Arnold W. Shaffer, Weld County, Colo. This is a support area from 20 to 125 miles from a possible target area for a 50X ground burst for the June exercise. The principal industry is livestock, and I would like to know (1) to what extent the meat of livestock exposed to such a fallout would be affected, and (2) to what extent growing field crops are affected?

DR. BUGHER: We have had a certain amount of experience with the livestock problem around this Nevada Test Site, and cattle and horses have been injured from fallout on their backs, and we still have some of the cattle that were originally injured at the Alamogordo test, the very first bomb test. We have those cattle at Oak Ridge. They did have skin burns, but no other damage internally. There is no reason why the meat from such animals would not be perfectly all right for food, provided the animal, on being slaughtered, were carefully skinned if its skin were heavily contaminated. The flesh itself would not be a problem.

QUESTION: I am Barbara Fox from Lincoln, Nebr. As a civil defender and housewife, it seemed to me that after reading the literature that was prepared that water was most essential. I enlisted the help of the canneries in canning water for civil defense and emergency use, which I anticipate will be placed in the grocery stores where it will be available to all housewives who are planning to stock their shelters. Would you care to comment on this provision in the light of your earlier remarks?

DR. BUGHER: I think the method insures a clean, safe water supply, particularly for drinking purposes. In a situation of extensive disaster the problem of providing safe water would be related to the problem of bringing such material in from an area less damaged, but as far as producing safe water, this method would be completely adequate.

QUESTION: I am Robert Bondy of New York City. We have heard this morning the significance of blast, and you have stated that under certain conditions that prediction of the area of fallout can be made with fair exactness. There is one imponderable that I don't quite understand as to how it fits into the situation. Your element of prediction here, I assume, counts on the bombardier hitting the right spot. Suppose the evacuation program is carried forward in the light of this prediction, and the bombardier misses the spot and the fallout is in the area of the evacuation?

DR. BUGHER: I think you can characterize that as nothing but a most unfortunate situation. It is an illustration of how difficult it is to be sure of anything in this whole area. One works on probabilities and tries to make a reasonable allowance for the uncertainties. You may find a prediction is just wrong, and doesn't meet what the enemy had in mind. That, of course, would be most tragic. I really haven't any adequate or better suggestion for that situation.

BIOMEDICAL EFFECTS OF THERMAL RADIATION

BY DR. HERMAN ELWYN PEARSE, *Professor of Surgery at the University of Rochester. Consultant to several Government departments, notably the Atomic Energy Commission's Division of Biology and Medicine. Consultant to the Armed Forces Special Weapons Project*

After the Bikini test, I was asked to go to Japan as a consultant for the National Research Council to survey the casualties in Nagasaki and Hiroshima. Being a surgeon, I was greatly impressed with the magnitude of the medical problem from burns and wounds very largely caused by flying missiles. They constituted roughly 85 percent of the casualties in Japan. I might say that this is the only experience we have had where humans have been subjected to an atomic bomb, and so is the only source of any statistics, but one must bear in mind that changing the conditions in a variety of ways would change the results.

It is not very meaningful, from a medical standpoint, to discuss which of these injuries is more important; that is, whether burns, blast, or ionizing radiation is more important, because they are all important. In every one there are unknown factors that need careful study in order that our doctors may give the most intelligent medical management. When I came back from Japan, I enlisted the support of the Atomic Energy Commission to study this problem, because these burns, unlike the burns seen in civil life, were due to a very brief exposure to a high intensity heat. It was an on-and-off situation. In civil life the burns are ordinarily due to a more prolonged exposure with contact on the skin. Secondly, the heat was radiated through the atmosphere, very much as the heat from the sun is radiated through the atmosphere. In fact, this is a good simile, because the spectrum of the bomb is not unlike that of the sun; and if you can imagine being in a space ship and getting a little too close to the sun, you would get levels of heat that would be comparable to those to which individuals may be exposed near a bomb.

In Japan the burns were the most urgent problems. I don't say they were the most important problem. They were the most urgent, because, according to Siezuki, 90 percent of those who sought aid in the first week did so because of burns. This produced a very large first aid medical problem.

Not knowing whether the physical factors that produced these burns made them any different from the burns seen in civil life, it seemed obvious

that studies should be made to analyze the characteristics of the lesion. How was it influenced by varying the amount of energy which would be comparable to different distances from the bomb? How was it influenced by changing the time of exposure? How was it influenced by the temperature of the environment? In Japan it was an August day, the people were lightly clothed, and they were out in the open. In our part of the world we have some pretty cold weather occasionally. We wanted to know what the effect of the ambient temperature would be. We wanted to know whether the healing was the same and whether the actual lesions looked like those from other burns. We wanted to know how the lesions could be protected against and how they should be treated. Our only recourse was to go into the laboratory and try to reproduce the burns in animals in a manner that would simulate that of the bomb.

It happens that the pig has a skin that is most comparable to that of the human. It is about the same thickness, and has about the same anatomical characteristics. In fact, one can find many other characteristics of the pig that are comparable to the human. We used pigs because we wanted to compare the lesion in the pig to those that we would produce on our own arms.

Our first problem was to find a source of heat intense enough to simulate the bomb. We tried two ways: One was igniting combustible materials that would burn quickly with an intense heat. We tried many materials and found that magnesium did very well—magnesium like the flash powder that a photographer uses, but much more of it. It burns in about three-tenths of a second. Later we found this was very fortuitous, because the atomic bomb also produces burns in about three-tenths of a second.

Then we tried another way—that of having a constant source of heat. We interposed shutters and diaphragms—diaphragms to regulate the amount, shutters to regulate the time. We found that the best way to do this was to take a big carbon arc searchlight and change the mirror in it to an ellipsoidal mirror, which would focus down the energy from the light onto a spot. Then with the timing shutters and diaphragms, we could do just as you do when you make a picture. We could stop down our shutter to any desired level of energy, we could go to a fraction of a calorie, and we could adjust our shutter from a range of time of one-tenth of a second up to 100 seconds or more.

After we studied these lesions in the laboratory, we were confronted with the problem of whether we really simulated the effect of the bomb. The only answer to that was to go into the field and do the same things, in order to prove the validity of our experimental laboratory work.

The first thing we wanted to know about the field tests was whether or not we could get information about the actual time, energy, and spectrum of the bomb which we could take back into the laboratory and use

to adjust our equipment. This we did in a number of participations in nuclear tests. I will tell you that the lesions that are produced on the side of a pig by a carbon arc light or by burning magnesium are indistinguishable either from surface appearance or microscopic changes from those produced by the bomb itself.

Then we observed the healing of the wounds, and we found again that the wounds healed in the same manner as those that we had produced in the laboratory. There was some difference in these lesions from the ordinary burns of civil life, but I would predict, from what I learned from experiments, that the difference is on the good side. The burns look worse; they are often charred, but they may not penetrate as deeply, and the char acts as a dressing, nature's own dressing. The scab solidifies, and the healing process goes on under that scab, after which the scab is sequestrated, and the healed surface is revealed beneath.

We wanted to know how the spectrum would change the severity—and we found out both in the laboratory and in the field by interposing selective filters between the beam of heat or light and the animal. We needed to know this because there is some change in the spectrum not only of different weapons, but also with different climatic conditions. We knew, for example, that a high humidity will absorb more infrared radiation. We found, in summary, that the longer the wave length, the more energy was required to cause the same severity of burn. The same severity is caused by a small amount of ultraviolet radiation, a little bit more of visible radiation, but quite a lot more of infrared radiation.

We wanted to know the time in which the burning occurred, because it's of importance to know whether you have time to duck. We did this in three ways. There are two components to a bomb burst; one is the initial flash, which is very bright, but lasts for a very short time—it has a very high intensity of energy. The second component is the enlargement of the fireball. If these burns occurred with the initial flash, then we had a relatively tough problem in the laboratory for that flash, in a nominal bomb, lasts something like two one-hundredths of a second. To determine whether or not the burn was caused by the initial flash or the fireball, we set up two openings. One was covered with a shutter; the other opening looked at the bomb. The shutter was so arranged that in between the initial flash and the fireball, it would slip over from one opening to the other. So we had an opening exposing the pig's skin during the initial flash and then it closed and the other one opened and exposed the skin during the fireball. We found that the initial blast caused no burn at any station at any time.

The next type of shutter to analyze the time of the burn was one that slid across a slot. It took three seconds to traverse. We found that with this sliding shutter, the burn was all over in about a half a second. It was a rather crude mechanism. So we went back into the field again with a

much more complicated shutter which had some 20 ports that would be open at various times and then close. For example, we would have a pair of ports, one of which would be open from zero to 100 milli-seconds, or one-tenth of a second. And then it would close, and the other one would be open from one-tenth of a second on; and then two-tenths of a second, two-tenths on; three-tenths of a second, then three-tenths on; and so on up to six-tenths of a second. I may summarize the findings by saying that in the interval of one-tenth to two-tenths seconds, the burn reached the maximum. That is, of all six intervals tested, the greatest burning occurred in the interval of one-tenth to two-tenths of a second. And in another group of shutters, it was seen that the maximum burning occurred around four-tenths of a second, and was complete by five-tenths of a second. If the shutter opened after six-tenths of a second, no burn occurred, in spite of the fact that there was measured thermal energy of a level sufficient to cause burning. It was above the threshold of burning. This illustrates that the rate of input of the energy is another factor which is important, in addition to the time, and the level of energy.

Finally, we wanted to know how we could protect against these burns. The military services were hard at work studying fabrics and the influence of the thermal energy on the fabrics. I didn't care what happened to the fabrics; I wanted to know what happened to the man under the fabric. So we conceived this idea, that the important factor in studying clothing was what happened under the clothing; how it shielded the animal with cloth of different composition, weight, texture, weave, and color. We have made a great many studies both in the laboratory and in the field on this problem of the protective effect of clothing.

I might summarize by saying that if the clothing is light, it protects well. If it is dark, it does not protect so well. To show how color works, I had some playing cards including the four of hearts and the four of spades, and at one distance from the bomb, the spades all burned out but the hearts did not. At a closer distance, some of the hearts burned out, the spades caught fire, and the white card was unchanged.

We knew this color sensitivity was true of fabrics because some of the women in Japan had on dresses with a dark pattern. They were completely unburned under the light part of their dress, but the pattern of their dress would be burned into their skin in the black dots, or stripes. We know that color is important in protection. We also know that weight is important. For example, if you have 2 layers, an undershirt and a shirt, you will get much less protection than if you have 4 layers; and if you get up to 6 layers, you have such great protection from thermal effects that you will be killed by some other thing. Under 6 layers we only got about 50 percent first degree burns at 107 calories.

This may not mean anything to you until I tell you that on my arm when I had 2 calories, I had no burn. When I had 2½ calories, I had a first-degree burn. When I had 3 calories, I had a second-degree burn. So this is very critical. We all take from 2,000 to 5,000 calories a day in our food. One calorie is the heat required to raise one gram of water one degree centigrade at certain pressure levels and it may make the difference between no burn and a second-degree burn which, if in large enough extent, may be fatal. Thus it is seen how critical a problem we are dealing with in protection. If we can just increase the protection a little bit, we may prevent thousands and thousands of burns.

Now, one final and very important thing that we discovered in the laboratory was that if the cloth was right against your skin, it would give very little protection. For example, to produce a 50-percent level of second-degree burns on bare skin required 4 calories. When we put 2 layers of cloth in contact, it only took 6 calories. But separate that cloth by 5 millimeters, about a fifth of an inch, and it increases the protective effect 5 times. The energy required to produce the same 50-percent probability of a second-degree burn is raised up to 30 calories. So if you wear loose clothing, you are better off than if your wear tight clothing.

This is what we are doing. We take all the information we can get from analysis of the Japanese. We take all the information we can get from laboratory experiments. We come into the field to try to validate those experiments in order to gain more information about the characteristics of this thermal burn. Our reason for doing this is to gain fundamental facts so that we will be in a much better position for military prediction, for civilian protection, and finally for good medical management.

BLAST EFFECTS ON STRUCTURES

BY DR. BRUCE JOHNSTON, *Professor of Structural Engineering, University of Michigan*

When you return to the test site and observe the physical changes in the structures that have taken place, those changes will have been produced by blast, more specifically, produced by pressure differentials, which is the term which I would like to emphasize this morning in discussing the blast problem.

I'd like to speak about this matter of pressure for a moment. How often does it occur to you that we live in an atmosphere that presses in around us at a pressure of 2,000 pounds per square foot? We don't feel this pressure, because internally there exists the same pressure. As a result, there is what we call pressure equalization: the pressure outside is the same as the pressure inside. The pressure of 2,000 pounds per square foot, of course, varies with the altitude. We find this true when we change altitude in an airplane. Then the pressure differential changes and we feel it in our eardrums.

Caisson workers who build foundations for dams and bore subway tunnels sometimes work under several thousand pounds more per square foot than the 2,000 pounds that they normally live in. They can only do this by adjusting to the change gradually, so that the internal pressure is always almost equal to the external. If they do not do this, and as a result have a pressure differential, then a very serious sickness, called the bends, or death may result.

The same thing happens to a structure. It gets the bends if a big pressure differential is suddenly applied.

Now we can design submarines for many thousands of pounds pressure per square foot. If you go 32 feet deep in the water, the pressure increases from 2,000 pounds atmospheric pressure to 4,000 pounds. At 64 feet it becomes 6,000 pounds. These are pressures greater than we have to design for on the fringe of an atomic blast where there is a chance for structural survival. So this matter of designing for pressure is not novel.

If I were given my choice of what to be in at 2,000 or maybe a few hundred feet from ground zero of an A-bomb tomorrow, I would ask to bury a submarine 10 feet below the surface. I'd feel quite safe in the submarine. In the case of an H-bomb I would have to be much further out than that.

Although the pressure differential is a major feature of the atomic blast waves, there is more to blast. Let's talk about wind for a moment. This is something structural engineers design for every day. If the wind is

blowing on a tall building, the combined atmospheric and wind pressure on the front face, where the wind piles up, may be 2,015 pounds per square foot in the case of a 100 mile-an-hour wind. Inside the building the atmospheric pressure may be 2,000 pounds per square foot. Away from the wind, the pressure may be 1,985 pounds per square foot. Pressure differential between the front face of the building and the inside would be 15 pounds. On the rear face of the building, away from the wind, there would be a 15-pound negative differential. The whole building is pushed sideways by the difference on the front face of 2,015 pounds and the force on the rear face of 1,985 pounds. The differential is 30 pounds per square foot, which is the value we design for.

In the shock wave from an atomic blast, we have both the inside-outside differential and the frontside-rearside differential almost simultaneously—this gives the building a teriffic slap when the pressure is on just one side. After the shock front passes two things take place, the building is encompassed in a crushing force from all sides, and momentarily, a wind gust tends to push it sideways because the air builds up on one side and tapers off on the other. However, the net result is one of crushing from all sides.

To pick some figures out of the air that have no relation to any particular bomb but which are typical of what we might have, you might have 4,500 pounds per square foot on the front face, 3,500 downward, and 3,500 pushing in from the rear. These are changing very rapidly. It's all over in a second. The overall lateral differential of 1,000 psf is partly due to the changing pattern of the pressure wave and partly due to the wind. Inside the building, if it were a bomb shelter completely enclosed, for example, the pressure would still be 2,000 pounds per square foot. So we would have local differential pressures of 2,500 pounds per square foot pushing in the front face, 500 pounds per square foot differential on the roof and sides, and 2,000 psf differential pushing in on the rear wall—two problems simultaneously—the submarine problem or resistance to crushing pressure, and the wind problem, or design for a lateral push. The overall differential pressure between front and rear is what causes the building to collapse with sidesway, or, if not anchored down, to roll over. The differential pressure between outside and inside causes local failure of walls, windows, and doors, bending them inward.

Usually, when we design a structure for a hurricane wind force, we treat that force as if it were a static or steady load. If the wind doesn't have any gustiness, it is, in effect, a static load pushing against the building. We cannot deal with a sudden or "shock" load in the same way with any accuracy. It would only be chance if the effects of a suddenly-applied pressure differential were the same as if it were applied statically. If the blast wave passed quickly enough, the structure might stand several times as much momentary peak pressure as it would statically if the pressure were

applied for a long period of time. On the other hand, a longer duration of suddenly-applied pressure might cause more damage than the same load applied statically. Dynamic analyses, as they are called, are important in the accurate prediction of what happens to a structure in a rapidly-passing blast wave. Such analyses require a different approach to design than is customary in conventional practice.

There are two types of design problems. One is the complete protection problem involved in the case of a bomb shelter or a particularly important building, such as a telephone exchange or a hospital, in which we must eliminate windows if we are going to avoid injury to the people at the fringe area where general destruction might occur.

There is another approach that is much more economical although applicable primarily to heavy industry. This is the idea which has been advanced by FCDA and others to use frangible walls and permit rapid pressure equalization. The best type of quickly failing or frangible wall probably would be corrugated asbestos, or gypsum board, or something similar that would disintegrate immediately and not cause serious missile trouble. The interior pressure could then rise, just as it does more gradually in the human body in the case of the person who adjusts to work in a caisson. He has pressure equalization and doesn't feel the external pressure at all. The same thing can happen to a structure if we permit the pressure to get inside of it quickly enough. The advantage of this approach is the minimizing of damage to the main structural frame, roof, and floor system.

The foregoing approach requires separate protection for personnel. They must have shelters, but they can be provided at much less cost than required for a protective building as a whole, and if the building houses heavy industrial equipment, that equipment may not be seriously damaged. We may learn something regarding the damage to such equipment in the present test program.

In summary, we have discussed this morning those features of the atomic blast wave that cause primary structural damage. Also, in closing, we have briefly mentioned two alternative approaches to design. Obviously, the short time available has permitted only a very superficial examination of these problems but it has been a privilege to have had the opportunity of presenting them to you.

QUESTION: Can you explain a little of the backlash pressure? Does that apply the same way?

DR. JOHNSTON: You mean, the negative phase?—Well, these are negative phases which we often ignore. However, if the wall of a building were damaged by the positive phase tending to crush it in, or if it were much weaker outwardly than inwardly, as might be if it were lightly attached to the horizontal axis of the wall, then it might very well fail in the negative phase where it didn't fail in the positive. If a structure, though, is just

as strong regarding outward pressure as it is inward, I would think that we were on the safe track by just designing for the positive phase.

QUESTION: Approximately how long for an average structure—I realize this is sort of a difficult question in a general sense, but approximately how long for an average structure would it take for pressure equalization?

DR. JOHNSTON: The question was, approximately how long in an average structure would it take for pressure equalization to take place? I don't know that I could answer that for an average structure, but if it is specifically designed with frangible walls, it will take place in a few thousandths of a second, because it only takes that long for these walls to fail—a small structure, let's say, with corrugated walls—will fail in two or three thousandths of a second. They will exert an impulse to the overall structure, but it won't amount to much. The primary effect, then, on the skeleton structure will be drag. I have not talked much about this problem because it is one we have been studying at the University of Michigan for several years—the use of frangible walls.

QUESTION: Could you discuss for us the probable effects of hills up to 1,000 feet high on the blast?

DR. JOHNSTON: No, in spite of the introducer's flattering remarks, I am not an expert on blast at all. I'm just a structural engineer who is interested in the effects of blast on structures, and I cannot discuss shielding with any authority at all.

TECHNICAL FACILITIES, EQUIPMENT, AND OPERATIONS AT NEVADA TEST SITE

In view of the varied interests represented in almost every test, the technical facilities at NTS—and particularly those which are used again and again—must be flexible.

Air drop targets are a surfaced cross, with concentric circles marked, and lighted for predawn shots. They are surrounded by structures and instruments much as those described below.

Test towers are of various heights and strengths, depending upon the condition of the test. They have in the past most frequently approximated 300 feet, although lower towers have been used. Four of 500 feet and 1 of 400 feet have previously been announced for the present series (spring 1955), heights now found feasible and adopted to increase offsite public safety.

The strength is varied according to the weight and size of equipment the tower will support. They are designed to use as little material as possible, partly for economy but primarily to reduce the quantity of vaporized material which will contribute to the radioactive cloud and fallout.

Unvaporized pieces of towers on some shots have been thrown for considerable distances and constitute a hazard affecting the placement of maneuver personnel.

A device to be tested, detection equipment, and other accessories are contained in a room at the top of the tower, called the "tower cab." There is usually an elevator, which is removed prior to the detonation.

There are *towers for other purposes,* such as collimators, photography, and television.

Instrumentation and Structures: Over the past few years, improvements in the methods of testing nuclear devices have been as marked as the improvements in weapons themselves. This is particularly true of instrumentation and electronics engineering. In developing faster, more precise instruments the test organization has turned to trained manpower throughout industry, Government, and universities. Developments originating in this program have, as a by-product, contributed to the general development of instrumentation applicable to many other fields.

The experiments require instrumentation ranging from very costly and complex electronics systems housed in monolithic, heavily-shielded underground recording shelters, to inexpensive and simple film badges and indenter gauges. There are cameras with framing rates in ranges from a few frames a minute up to 7,000,000 a second. There are neutron detectors, thermal instruments, and blast gauges.

Each firing area is equipped with several permanent instrument stations, in addition to a wide variety of temporary stations and test structures used for 1 shot only, or at most for a single series. Most stations, either permanent or temporary, receive power, telephone communications, and timing signals from permanent local distribution points within various firing areas. A few outlying stations rely on portable generators and radio for these services.

Underground Instrumentation Bunkers: Coaxial cables extend from the cab to an underground instrumentation bunker. They run direct from cab to bunker by the shortest practical line, rather than down the tower and across the surface of the ground, in order that signals will reach the bunker before radiation can shortcut the cables and before the cables are themselves disintegrated. In the ground, cables are laid in transite conduit, so that individual cables which may become defective with use can easily be pulled out of the conduits and be replaced.

In some tests collimator systems have been used to record gamma or neutron radiation. Exact positioning is a necessity. There is a declining height system of towers and of concrete walls extending from the tower to an underground recording station. Each tower or wall supports a heavy mass with several holes in it. These holes are aligned so that there is direct line-of-sight from the atomic device to the underground recording equipment. The holes provide clear paths for gamma radiation or neutrons, with heavy shields insuring that gamma or neutrons from regions outside the line of sight will not reach the detectors underground.

Large underground bunkers or blockhouses for recording instruments have been built close to ground zero in several firing areas. These massive concrete and steel units are topped with a thick mound of earth, the surface of which is stabilized by an asphalt coating. Depending on their nature and the type of equipment used, these blockhouses cost from $100,000 to $600,000. They are built to withstand effects of detonations. Their initial cost is high but they may be used for several test operations.

The underground bunkers not only protect the instruments against blast, but also against radiation. Without shielding, the intense radiation fields which accompany the detonation would immediately fog all film, ionize the gases in the electronic tubes, and cause other severe damage, putting the equipment out of order.

Underground bunkers at NTS are used to record blast, heat, neutron, or gamma radiation, or for taking photographs, but they vary considerably in design.

While data from an experiment may be recorded in a few millionths of a second, many months of work go into constructing and equipping a bunker. The scientists responsible for setting up the equipment work for months in home laboratories and fabricating plants before working

the clock around for weeks or months to install it in the bunker. Working with them at NTS are construction and electrical contractor personnel.

Final calibration of instruments, checking circuits, testing of signal strengths, time signal relays, and electrical power behavior are performed during the week immediately preceding a detonation.

Prior to the shot, hundreds of switches for the recording instruments are preset, then the bunker is evacuated with no person inside at shot time. Heavy leadlined doors like the bulkhead doors of a large warship are closed and sealed. When the massive outer door swings shut the bunker is ready to receive and record the data from the assortment of instruments aboveground—instruments which may be vaporized in the instant of detonation.

On a fixed schedule prior to the shot, the timing mechanism in the control room back in Yucca Pass sets in motion the whole mechanism at the tower, on the ground, and in block houses and bunkers in the area.

Frequently the most useful measurements are those of what takes place within the detonation itself. Since the measurements must be made in millionths of seconds—or less—the resolving time of equipment must be incredibly short. To catch the immediate early phenomena of the detonation, the detectors and gauges must be placed on the tower in close proximity to the unit being tested. This, of course, means that the detectors are almost instantly vaporized, but in the millionths of a second before they are destroyed, they transmit the all-important signal to the recording devices in the bunker.

Instrumentation in the bunker consists mostly of power supplies, amplifiers, oscilloscopes, cameras, and other recording devices. Large coaxial cables carry the signal to the recording machines from the gauges and indicators outside.

The electronic recording circuits respond extremely rapidly. They can be made to operate in a few hundred-millionths of a second. A great deal of light is required to write on photographic film in such a limited time. Unless special precautions are taken, this light would badly fog the film during the many minutes the instrument is waiting for its signal to be given. To solve this dilemma the electron beam is reduced in intensity and deflected off the screen prior to zero time. At the last possible instant it is necessary to raise this intensity to its required value. By an ingenious arrangement, the coaxial cable is tapped so that the signal itself can trigger an intensifier. The signal, however, passes through a greater length of cable and hence appears at the scope to be recorded a micro-second or so after the intensity has been increased.

The record is of very short duration. Fortunately, however, the fluorescent oscilloscope screen retains the image briefly after the electron beam has swept across. The persistence of the image, analogous to a modern tele-

vision tube where no flicker is discernible to the eye, is sufficient to permit permanent recording on the photo film.

These films are the raw data from which the results of the experiment are interpreted.

After the shot, re-entry to the building and recovery of the data is made as soon as radiological safety precautions permit. This is normally within a few hours after the blast.

The Control Point

The Control Point in Yucca Pass is the brain—the nerve center—of every test operation at NTS.

From it radiate the myriad communication lines and channels required for receiving information and transmitting orders to control a complex operation. There are long distance telephone lines and teletype circuits to receive information from and provide information to Washington, Los Alamos, Albuquerque, Berkeley, and elsewhere. Into it feeds weather information from a class A weather center in Mercury which receives information from all over the world through Air Weather Service and U. S. Weather Bureau networks, as well as up-to-the-minute information on local conditions through stations manned specifically for these operations.

The control of as many as 100 aircraft with such varied jobs over a few square miles of land requires the utmost reliability of communications. Air Force personnel and equipment for this purpose are stationed at the control point.

Beyond the control of the operation there is also the control of the many experiments themselves. There are filaments to be turned on, power must be applied to many circuits, camera shutters must be opened and closed at exact moments, ultrafast as well as normal movie cameras must be started, blast-proof doors must be secured, some signal lights must be turned on and others turned off. In static tests the nuclear device itself must be armed and fired. These and hundreds of similar details must be taken care of without fail in proper order and at predetermined times so that the desired information can be obtained.

This control of experiments is provided by a device known as a "sequence timer" located in the control room. The device sends out electric signals which activate relays to perform the above tasks; it starts clocks to measure the detonation; and it even starts itself—in case of an air drop—when the bomb leaves the dropping aircraft.

All instruments closer than 7 miles to a shot are remotely operated. A few instruments are completely self-contained and are activated by light or other characteristics from the nuclear explosion, but most are put into operation by time signals from the Control Room. The early time signals—

from minus an hour to minus 5 minutes—are used primarily for such things as turning on power for electrical and other recording equipment, opening protective blinds, and closing air-conditioning vents. Later signals, coming within a few seconds of zero time, are used to start high-speed recording equipment and other test instruments which are carefully programed and require very accurate timing relative to detonation time. For instance, at minus 5 seconds a series of rockets may be fired to set up rocket trails for observation by high-speed cameras.

A complex instrument panel in the Control Room reflects these intricate operations. The first section of the panel is used only for air bursts, receiving signals from the bomber indicating release and, seconds later, recording the detonation. The second and third sections contain the frequency control equipment for the motor-generator set which supplies power to the timing equipment, with voltage recorders, connected to various points in the target area—thus assuring accurate timing—and records for wind velocity and direction. In order to activate test equipment at the exact time, very precise control of the frequency for the timer is required.

APPENDIX A

Field Exercise Participants

RESCUE SERVICES

Name and Address

Brohammer, Elmer A., St. Louis 18, Mo.
Chenoweth, W. A., Baltimore 8, Md.
Clawson, Ray M., Ogden, Utah
DeVivier, J. F., Denver 2, Colo.
Eldredge, W. F., Miami 35, Fla.
Felds, Theo. H., Houston 2, Tex.
Harkins, J. M., Butte, Mont.
Harlow, Peter C., Detroit 10, Mich.
Johnson, Harry R., Madison, Ill.
Knight, Richard C., Alexandria, Va.
Leach, James P., Jr., Memphis, Tenn.
Marchand, Stephen E., Wichita Falls, Tex.
Mason, Rex A., Mentor, Ohio
McBride, Melvin E., Washington 12, D. C.
McVeigh, J. P., Queens, New York City

Name and Address

Milem, W. W., Alloy, W. Va.
Palmer, Robert T., Minneapolis 9, Minn.
Priolo, Thomas P., Chevy Chase 15, Md.
Rainbolt, J. D., Houston, Tex.
Reed, Alfred W., Turnwater, Wash.
Ridout, William H., Placerville, Calif.
Risedorf, George F., Schenectady, N. Y.
Robison, Gerald J., Marion, Ind.
Scherer, Richard D., Wichita 18, Kans.
Schick, Joseph W., Wheaton, Md.
Stolsig, John A., Lebanon, Oreg.
Taylor, Arnold L., New Orleans, La.
Walther, Charles F., Omaha, Nebr.
Watson, Louis M., Honolulu 16, T. H.

POLICE SERVICES

Abbott, Roger L., Sacramento, Calif.
Anderson, Ray L., Wichita, Kans.
Andrus, James V., Wichita Falls, Tex.
Balaze, Louis, River Rouge, Mich.
Baldwin, Thane M., Greybull, Wyo.
Boyles, Raymond W., Charleston, W. Va.
Brandon, James E., Boise, Idaho
Browne, William D., Portland, Oreg.
Cahill, John J., Bemidji, Minn.
Cavender, Charles M., Indianapolis, Ind.
Dahl, Raymond A., Milwaukee, Wis.
Derden, James B., Fort Worth, Tex.
Floyd, Roy Martin, Denver 10, Colo.
Gallagher, Joseph James, St. Louis, Mo.
Gantt, Irene, Marion, O.
Hall, Charles Lindley, Olympia, Wash.
Hammel, Beatrice, Reading, Pa.
Heener, J. Conrad, Des Moines, Iowa
Hickey, Janet S., San Jose, Calif.
Keiter, Bernard L., Dayton, O.
Maggianett, Dan, Youngstown, O.
McDonald, Ross R., Sacramento, Calif.
Morris, Richard W., Syracuse, N. Y.
Oates, Donald E., Holt, Mich.
Racki, Henry C., Naugatuck, Conn.
Schmoker, Fred M., Cheyenne, Wyo.
Starr, Starr D., Orlando, Fla.
Stone, Albert E., Syracuse, N. Y.
Woodward, Fred F., Memphis, Tenn.
Wrenn, Leo Harold, New Britain, Conn.

SANITATION SERVICES

Bain, Thomas Edwin, Portland, Oreg.
Griffin, Ralph C., Fort Worth, Tex.
Handorf, Everette C., Memphis, Tenn.
Klassen, Clarence, Springfield, Ill.
Mansur, Richard H., Augusta, Me.
Thatcher, Lynn Mathews, Salt Lake City, Utah
VanderVelde, Theodore L., East Lansing, Mich.

FIRE SERVICES

Name and Address

Allen, Ross W., Sacramento 21, Calif.
Allison, Lawrence, Alliance, Ohio
Almgren, Louis R., San Diego, Calif.
Ames, Norton T., Oregon, Wis.
Blakslee, Judson D., Battle Creek, Mich.
Bowers, Russell, Reading, Pa.
Bowhay, Harold P., Sacramento 1, Calif.
Crawford, Ellsworth, Denver 14, Colo.
Davey, Ersal, Crownsville, Md.
Ellis, Ezekial, New Orleans, La.
Farr, Francis W., Sparks, Nev.
Ford, Laurence, Redding, Conn.
Gates, Elmer, Las Vegas, Nev.
George, Burton O., Berryville, Ark.
Hales, Harvey, Monroe, La.
Hopkinson, Ernest, Las Vegas, Nev.
Iverson, Ellis "Buff", Lincoln, Nebr.

Name and Address

Laughlin, John, East Providence, R. I.
Martin, Leo, Mercury, Nev.
McLendon, Jesse H., Santa Rosa, Calif.
McGaughey, Thomas, Wichita, Kans.
Moore, Willard, Yakima, Wash.
Querhammer, Alvin, Crystal Lake, Ill.
Reinelt, Harold, Detroit 5, Mich.
Riegel, Mason D., Sacramento 1, Calif.
Soracco, Frank, Flushing 66, N. Y.
Taylor, George R., Sacramento 1, Calif.
Taylor, Stephen H., Boise, Idaho
Tiller, Ray, Waterloo, Iowa.
Walker, William H., Pierre, S. Dak.
Warnall, Francis, Kansas City, Mo.
Weidner, Leo, Portland 2, Oreg.
Wilson, George W., Jr., Port Neches, Tex.

ENGINEERING SERVICES

Cuney, George, Newton Center, Mass.
Dauenhauer, Fred W., Columbus 15, Ohio
Dornblatt, Bernhard M., New Orleans, La.
Ilgenfritz, Walter, Denton, Tex.
Kennedy, R. Evan, Portland, Oreg.
McCoy, Herbert V., Collinsville, Ill.
Mader, Earl, Thomasville, Ga.
Nesheim, Arnold S., Battle Creek, Mich.
Nichols, Hall, Wellesley, Mass.
Pope, R. R., Broomall, Pa.
Roe, Frank C., Webster Groves 19, Mo.
Schaefer, William A., Minneapolis, Minn.
Spratlen, Frank, Denver, Colo.
Swanson, Herbert S., Los Angeles 39, Calif.
Thompson, J. Neils, Austin, Tex.
Tilney, Bradford, New Haven, Conn.
Wells, Roy, Geneva, Ill.
Wolf, Whitney, Winter Park, Fla.
Woodward, Lloyd A., Denver, Colo.

COMMUNICATIONS

Black, Guy, Berkeley 9, Calif.
Breuer, Herbert J., Sacramento, Calif.
Brown, Henry M., Battle Creek, Mich.
Byrd, Victor E., Sacramento 21, Calif.
Crabtree, William R., El Cerrito, Calif.
Card, Horace W., Temple City, Calif.
Cook, Donald R., Fresno, Calif.
Hughs, Kenneth E., Sacramento, Calif.
Jones, Frank V., Davis, Calif.
Kelley, Thomas J., Davis, Calif.
Linsey, Harold V., San Diego, Calif.
MacMurphy, Brower C., Centerville, Calif.
Miller, Alfred P., Battle Creek, Mich.
Pinkerton, Irving W., Glendale 1, Calif.
Sawyer, Brooke E., Redlands, Calif.
Wentsch, Harold E., Sacramento, Calif.
Whiteman, Walter E., Anaheim, Calif.
Whitfield, Willard D., Sacramento, Calif.
Whiting, William E., Bakersfield, Calif.

MASS FEEDING

Name and Address

Bone, Arthur E., Paoli, Pa.
Bovee, Dorothy L., Mt. Vernon, Va.
Carpenter, Frank T., Hopkins, Minn.
Cascio, Ben, Palisades Park, N. J.
Caubet, Jean Baptiste, Dearborn, Mich.
Clarke, Eugene C., Claremont, Calif.
Cooper, Max J., Las Vegas, Nev.
Deal, Paul, Boston (Dorchester), Mass.
dePietro, Marguerite, Glenolden, Pa.
DeTalente, George, Phoenix, Ariz.
Detrich, Karl A., Philadelphia 20, Pa.
Dinkler, Carling, Atlanta, Ga.
Droescher, Elizabeth C., Washington 16, D. C.
Economou, Peter G., Buffalo, N. Y.
Fehlman, Hazel A., Baldwin, Colo.
Germanovich, Milan, Cleveland Heights 21, Ohio
Gilpin, Vernon T., Arlington, Va.
Goad, Carmen, Oakland, Calif.
Gurney, Foster, Chicago, Ill.
Hasting, Mrs. Kester, Washington, D. C.
Herndon, Vernon, Chicago, Ill.
Hill, Carl F., Rosemead, Calif.
Isbell, Marion, Chicago, Ill.
Jensen, Ralph, Rosemead, Calif.
Jordan, Mrs. Dewey, Dallas, Tex.
Keller, Floyd M., Las Vegas, Nev.
Keller, Reinhold, Redwood City, Calif.
Kraus, Walter, Coos Bay, Oreg.
LaBlanc, Wharton A., Baton Rouge, La.
Landstreet, Arthur F., Memphis, Tenn.
Langley, Norbert, Waldorf, Md.

Name and Address

Lappin, Robinson, Washington, D. C.
Leininger, Helen E., Jackson Heights, Long Island, N. Y.
Lock, Curt, Grand Rapids, Mich.
Lovelady, Talmage, Worland, Wyo.
Malchiodi, W. J., Erie, Pa.
Manning, Farley, New York, N. Y.
McAllister, C. J., Waldorf, Md.
McCartney, Gladis, Baton Rouge, La.
McDonough, C. T., San Francisco, Calif.
Moncue, Vernon, Powell, Wyo.
Mondau, Louis J., Tacoma, Wash.
Myers, Thomas, Las Vegas, Nev.
Neumann, N. H., San Diego, Calif.
Packard, Arthur, Mount Vernon, Ohio
Rasmussen, Peter, San Francisco, Calif.
Rote, Max W., Jr., Silver Spring, Md.
Rulon, Watson B., Jr., Washington, D. C.
Russell, Elsie Wells, Los Angeles 4, Calif.
Schensul, Joe, Hickory Corners, Mich.
Shank, Paul V., Denver, Colo.
Smith, Clayton R., Long Beach, Calif.
Smith, John, Dayton 5, Ohio
Smith, Kurt, Philadelphia, Pa.
Smith, Robert N., Oklahoma City, Okla.
Stewart, Malcolm L., Woodland Hills, Calif.
Stukes, Mrs. S. G., Decatur, Ga.
Ward, Helen G., Chester, Va.
Washam, Frank O., Chicago 1, Ill.
Wheeler, William O., Indianapolis, Ind.

CASUALTY CARE SERVICE

Aird, Margaret, St. Louis 8, Mo.
Ameden, Alden, Rowayton, Conn.
Anderson, Charles, M. D., Detroit, Mich.
Benedetto, Father, New Orleans, La.
Blankenship, Charles F., M. D., Kansas City, Mo.
Boring, Jessie Francis, Kansas City, Kans.
Bridges, Lidwell S., Baton Rouge, La.
Burbridge, Talmadge, Salt Lake City, Utah
Canaipi, Victor V., Providence 6, R. I.
Chapman, Richard, Amarillo, Tex.
Coburn, Edna P., Arvada, Colo.
Coffman, Jean B., University City, Mo.
Collier, Mary A., M. D., Wheat Ridge, Colo.
Coons, Edwin F., Seattle, Wash.
Davis, Eva Mary, Kansas City, Mo.
Davis, Henry Bell, Kansas City, Mo.
Dotson, Glen N., Golden, Colo.
Douglass, Margaret E., Wilsey, Kans.
Ebbinghause, William R., St. Louis 6, Mo.

Name and Address

Eckel, Charles L., Denver, Colo.
Elsea, Elmer C., Denver 7, Colo.
Fourrier, Daniel J., Dr., Baton Rouge, La.
Green, William M., New Orleans, La.
Grosman, Edmund W., Hamilton, Ohio
Guido, Joseph V., Seattle, Wash.
Guyer, Clarkson J., Denver, Colo.
Haapaniemi, Edmond M., Bellair, Tex.
Hammes, Kenneth W., Globe, Ariz.
Harte, Helen M., Holyoke, Colo.
Head, C. D., Jr., Dr., Denton, Tex.
Holcombe, Clifford F., San Antonio, Tex.
Homer, Willis H., Mansfield Center, Conn.
Hons, Alice B., Kansas City, Mo.
Howard, C., Jr., Nashville, Tenn.
Ives, Helen G., Topeka, Kans.
Jones, Frank Vaux, Jr., Davis, Calif.
Jones, Sam W., Knoxville, Tenn.
Koller, Dorothy R., Akron, Ohio
Lake, William E., Orange, Conn.
Landcaster, Richard R., Topeka, Kans.
Lande, Catherine H., Denver, Colo.
Lindquist, Paul, M. D., Denver, Colo.
Lohr, Curtis H., M. D., Clayton, Mo.
Losasso, Alta M., Denver, Colo.
Lucey, William C., Winnetka, Ill.
McBratney, Eugene B., Kansas City, Kans.

Name and Address

McClain, Otis M., Topeka, Kans.
MacDonald, Norman J., Erie, Pa.
Mason, Mont G., Ferguson, Mo.
Morris, Lafayette, Webster Groves 19, Mo.
Mott, James M., M. D., Topeka, Kans.
Motze, Russell O., Reading, Pa.
Mullen, Arthur J., Fairhaven, Mass.
Muir, Charles H., Schenectady, N. Y.
O'Malley, Neva C., Las Vegas, Nev.
Plumer, Herbert E., New Castle, N. H.
Roberts, Gertrude N., Denver, Colo.
Sanderson, Mildred T., St. Louis, Mo.
Schubert, Ruth A., Kansas City, Mo.
Scott, Melba M., Lincoln, Nebr.
Simmons, James M., Portland, Oreg.
Simmonds, James F., Chesterfield, Ind.
Smith, Aubigne, Bangor, Maine
Smith, Robert Leslie, M. D., Battle Creek, Mich.
Sullivan, John A., St. Louis 21, Mo.
Thomen, Martin K., Orange, Tex.
Watkins, Roland M., D. C., Kansas City, Mo.
Welch, Oliver D., Kansas City, Mo.
Whitney, John M., M. D., Battle Creek, Mich.
Wilson, Jack E., Houston, Tex.
Woodward, Opal B., Coffeyville, Kans.

FIELD EXERCISE OPERATIONS HEADQUARTERS

Blakslee, Judson D., Battle Creek, Mich.
Blanchet, William B., Battle Creek, Mich.
Boase, Alexander C., Sacramento, Calif.
Brown, Henry M., Battle Creek, Mich.
Burns, Robert C., Portland 12, Oreg.
Gebhard, Lloyd W., Battle Creek, Mich.
Gehrke, Elmer P., Cleveland, Ohio
Hurley, John J., Washington, D. C.
Johnson, C. L., Toledo, Ohio
Kessler, Irving
Kimberling, A. E., Battle Creek, Mich.
Lowe, Jack, Portland 12, Oreg.
Miller, A. P., Battle Creek, Mich.
Nesheim, Arnold L., Battle Creek, Mich.
Priolo, Thomas, Chevy Chase, Md.
Ross, W. A., Battle Creek, Mich.
Smith, Shirley, Oakland, Calif.
Smith, Robert L., M. D., Battle Creek, Mich.
Trowbridge, L. G., Battle Creek, Mich.
Tyrer, Andrew, Miami Shores, Fla.
Weaver, Leon, Battle Creek, Mich.
Whitney, John, M. D., Battle Creek, Mich.
Wood, Robert M., Cleveland, Ohio

Mobilehome Dealers National Association:
- Airstream Trailers, Los Angeles, Calif.
- Aljoa Industries, Gardena, Calif.
- Columbia Trailer Co., Van Nuys, Calif.
- Grand Trailer Sales, Jacksonville, N. C.
- Hawk Sales Co., Inc., Syracuse, N. Y.
- Idaho Trailer Mart, Boise, Idaho
- Kit Manufacturing Co., Long Beach 10, Calif.
- D. T. Singer Trailer Distributors, Salt Lake City, Utah
- Sparton Aircraft Co., Tulsa, Okla.
- Terry Coach Manufacturing Co., South Gate, Calif.
- Thompson Trailers, Elbridge, N. Y.
- Trailer Coach Association (Calif.)
- Travelezee Trailer Co., Sun Valley, Calif.

Mobile Homes Manufacturers Association:
- Mid-States Corp., Union City, Mich.
- Mon-O-Coach, Inc., Louisville, Ky.
- Pacemaker Trailer Co., Elkhart, Ind.
- Panelfab Products, Inc. (cabanas), North Miami, Fla.
- Peerless Manufacturing Corp., Fort Wayne, Ind.
- Quality Mobile Home Corp., Childton, Wis.
- Stewart Coach Industries, Inc., Bristol, Ind.
- Streamlite Mobile Homes Co., Chicago 9, Ill.
- Supreme Mobile Homes
- Vagabond Coach Manufacturing Co., New Hudson, Mich.

National Association of Frozen Food Packers.

National Association of Furniture Manufacturers, Inc., and member companies:
- Artistic Furniture.
- Baker Furniture, Inc.
- Beecher Falls Manufacturing Co.
- A. Brandt Co., Inc.
- Brandt Cabinet Works, Inc.
- Conant Ball Co.
- Crawford Furniture Manufacturing Co.
- Dillingham Manufacturing Co.
- Dunbar Furniture Corporation of Indiana.
- Edison Wood Products, Inc.
- Extensole Corp.
- Grand Rapids Chair Co.
- Habitant Shops, Inc.
- Haeger Potteries, Inc.
- Hekman Furniture Co.
- Imperial Furniture Co.
- International Furniture Co.
- William Intner Co., Inc.
- Jamestown Lounge Co.
- Jamestown Royal Upholstering Corp.
- Jamestown Sterling Corp.
- Kroehler Manufacturing Co.
- Kuehne Manufacturing Co.
- La-Z-Boy Chair Co.
- Lullabye Furniture Corp.

National Association of Furniture Manufacturers, Inc., and member companies—Continued

- J. L. Metz Furniture Co.
- Michigan Seating Co.
- Mueller Furniture Co.
- Phoenix Chair Co.
- Red Lion Table Co., Inc.
- Selig Manufacturing Co.
- Showers Brothers Co.
- Sieling Furniture Co.
- Simmons Co.
- Spearman Brothers Co.
- Springfield Furniture Works, Inc.
- Storkline Furniture Corp.
- Sun Glow Furniture Industries.
- Tayco Products, Inc.
- Thonet Industries, Inc.
- Tonk Manufacturing Co.
- Trimble, Inc.
- Widdicomb Furniture Co.
- Williamsburg Chair Factory, Inc.

National Association of Motor Bus Operators.
National Canners Association.
National Meat Canners Association.
National Records Management Council and participating companies:

- Art Metal Construction Co.
- The General Fireproofing Co.
- The Mosler Safe Co.
- The Paige Box Co.
- Remington Rand, Inc.
- National Restaurant Association.
- North American Van Lines, Fort Wayne, Ind.
- Paper Cup and Container Institute.
- J. C. Penney Co., New York, N. Y.
- Picture and Frame Institute.

Radio-Electronics-Television Manufacturers Association and member companies:

- Admiral Corp.
- American Phenolic Corp.
- Andrew Corp.
- The Antenna Specialists Co.
- Anton Electronic Laboratories, Inc.
- Belden Manufacturing Co.
- Bendix Aviation Corp.
- Chatham Electronics Division of Gera Corp.
- Cook Electric Co.
- Corning Glass Works.
- Dale Products, Inc.
- DuKane Corp.
- El-Tronics, Inc.
- Erie Resistor Corp.
- General Electric Co.
- Goldak Co.

Radio-Electronics-Television Maufacturers Association and member companies—Continued

The Hallicrafters Co.
Hughes Aircraft Co.
Hydro-Aire, Inc.
IDEA, Inc.
J-B-T Instruments Co.
Jefferson Electric Co.
JFD Manufacturing Co.
Jordan Electronics, Inc.
Keleket X-Ray Corp.
Landsverk Electrometer Co.
Lenz Electric Manufacturing Co.
P. R. Mallory Co., Inc.
Motorola, Inc.
The North Electric Manufacturing Co.
NRD Instrument Co.
Permoflux Corp.
Radiation Counter Laboratories, Inc.
Radio Corp. of America.
Remler Co., Ltd.
Simpson Electric Co.
Speer Carbon Co.
Sprague Electric Co.
Stainless, Inc.
Victoreen Instrument Co.

Reynolds Metals Co. (Aluminum), Louisville, Ky.
Rocklite Products, Ventura, Calif.
Safe Manufacturing National Association
Society of the Plastics Industry, Inc.
Survival Shelters, Inc.
Texas Industries, Inc., Dallas, Tex.
Upholstery & Drapery Fabric Manufacturing Association, Inc.
Union Carbide and Carbon Corp.
Venetian Blind Association of America, Inc.
Weber-Costello Co., Chicago Heights, Ill.
Western Union Telegraph Co.
Willys Motors, Inc., Toledo, Ohio
Z & W Machine Products Co., Inc., Cleveland, Ohio
Robert J. Zievers, Inc., LaVerne, Calif.

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